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RAILWAY GAUGES, (1)

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(*Concluded.*)

Figs. 17 to 21, pp. 173/91 to 194/112.

PART III.
GAUGE CONVERSIONS.

TABLE OF CONTENTS.

(1) See *Bulletin of the Railway Congress*, January and February 1924, p. 25 and 87.

CHAPTER X. — GENERAL CONSIDERATIONS.

In addition to the question of the choice of gauge to which to construct new railways, which has been dealt with in a previous article, it may happen that the problem presents itself in a new and more urgent form in cases where the alteration of the gauge of the existing lines has to be undertaken. This is always a costly operation and one which causes a considerable dislocation of the traffic during the transition period, and is therefore an operation which is not undertaken unless absolutely necessary.

It must also be considered whether it is more economical to double the existing line rather than to change the gauge, but if the existing narrow gauge is insufficient, double tracking is often merely a palliative, and it may still be necessary to deal with the gauge problem at a later date. This is not the case, however, if the narrow gauge is the gauge in general use in the country under consideration

The inconvenience which is experienced during the transition stage is a transitory one, but must be taken into consideration and compared with the advantages to be gained.

A point which is often raised against gauge conversions, even when this is done to obtain uniformity between the railways, is that the necessary capital may often be more usefully employed in constructing new lines. This appears to be a point which should be given consideration, but it may often be said that if a railway is able to raise the necessary money to convert the gauge, it should be still easier to find money for the construction of new lines.

Il is essential that the existing line should pay sufficient interest on the existing capital, and that the line in its reconstructed state should pay a return on this capital increased by the amount of the additional capital.

We give below a large number of examples of gauge conversions so that one may see what has already been done in cases similar to those which may be contemplated, and we will group this information into chapters as follows :

A) Chapter XI. — Absorption of a line by a railway which already possesses an important system laid to another gauge.

B) Chapter XII. — Reconstruction of a railway under different structural conditions.

C) Chapter XIII. — Reconstruction of a railway which has reached its maximum capacity.

D) Chapter XIV. — Reconstruction of a railway to another gauge for reasons of economy.

E) Chapter XV. — Standardisation of gauge of two lines or sections of lines which have a considerable interchange traffic.

F) Chapter XVI. — General standardisation of gauges in one country or territory.

In each of these chapters, we give the countries of Europe, and then those of other continents (Africa, America, Asia, Oceania).

TABLE 50.

List of railways of which particulars of gauge conversion are given.

RAILWAY.	COUNTRY.	Page No.
Antofagasta & Bolivia Railway	Chili	169/87 and 175/93
Angtung-Mukden (Railway)	China	174/92 and 178/96
Australian Government Railways	Australia	201/119
Baden (State)	Germany	182/100
Bagdad (Railway)	Anatolia	174/92
Bahia (Railway)	Brazil	170/88
Bahia to São Francisco (Railway)	Brazil	170/88 and 193/111
Baltimore & Ohio Railway	United States	196/114
Barbados Railway	Barbados	179/97
Beira Railway	Mozambique	169/87 and 186/104
Bengal Nagpur Railway	India	171/89 and 172/90
Bolivia Railway	Bolivia	175/93
Bombay Baroda & Central India Railway	India	171/89
Bosnia (Railway)	Bosnia	173/91
Cape Government Railways	South Africa	179/97 and 185/103
Carnatic Railway	India	171/89
Central of Brazil (Railway)	Brazil	170/88 and 194/112
Paraguay Central (Railway)	Paraguay	180/98 and 188/106
Congo (Railway)	Belgian Congo	175/93 and 186/104
Cooch Behar Railway	India	171/89
Cork & Passage Railway	Ireland	168/86
County-Donegal Railway	Ireland	168/86
Denver & Rio Grande Railway	United States	178/96 and 198/116
Dourado (Railway)	Brazil	180/98
Eastern Bengal Railway	India	171/89
Eastern Counties Railway	England	182/100
East Indian Railway	India	171/89
Eskdale & Ravenglass Railway	England	179/97
Erie Railway	United States	196/114

Table 50 (*continued*).

RAILWAY.	COUNTRY.	Page No.
State (Railways)	South Africa	173/91 and 185/103
	South West Africa	173/91 and 186/104
	Australia	201/119
	Baden	182/100
	Belgium	168/86
	Bosnia	173/91
	Cape Colony	179/97 and 185/103
	Chili	169/87
	Lagos	169/87
	Mesopotamia	180/98
	Natal	179/97 and 185/103
	New Zealand	179/97, 202/120 and 203/121
	Palestine	201/119
	Poland	185/103
	Togo	169/87
Finn Valley Railway	Ireland	168/86
Funilense (Railway)	Brazil	170/88 and 194/112
Great Northern Railway	Ireland	168/86
Great Southern Railway	India	171/89
Great Western Railway	England	182/100 and 199/117
Great Western Railway	Brazil	170/88 and 180/98
Great Western Railway	Canada	195/113
India Branch Railway	India	178/96 and 199/117
Indus Valley Railway	India	171/89
Jaffa-Jerusalem (Railway)	Palestine	201/119
Jodhpur Bikaner Railway	India	171/89
Lagos Government Railways	Nigeria	169/87
Leopoldina Railway	Brazil	170/88, 176/94 and 179/97
Madras & Southern Mahratta Railway	India	171/89
Maleguano (Railway)	Argentine	169/87
Marica (Railway)	Brazil	180/98

Table 50 (*continued*).

RAILWAY.	COUNTRY.	Page No.
Maunch Chunk Road	United States	195/113
Mesopotamia Government Railways	Mesopotamia	180/98
Metropolitan Railway	England	183/101
Mexican National Railways	Mexico	178/96
Morvi Railway	India	171/89
Natal Government Railways	South Africa	179/97 and 185/103
New Zealand Government Railways	New Zealand	179/97, 202/120 and 203/121
North East Argentine Railways	Argentine	169/87 and 180/98
North Western Railway (State)	India	171/89 and 200/118
Noville-Taviers to Embresin (Railway)	Belgium	168/86 and 172/90
Otavi Railway	South West Africa	173/91
Western of Minas (Railway)	Brazil	176/94 and 177/95
Palestine Railways	Palestine	201/119
Paris-Orleans (Railway)	France	168/86
Pays de Waes (Railway)	Belgium	168/86
Prince Edward Island Railway	Canada	195/113
Punjab Northern Railway	India	171/89
Quincy Railway	United States	195/113
Recife and Sao Francisco (Railway)	Brazil	170/88 and 193/111
Rehenen (Railway)	Holland	185/103
Rio do Ouro (Railway) to the State	Brazil	170/88
Rio Grande to Bagé (Railway)	Brazil	193/111
Sceaux (Railway)	France	168/86
Sorocabana Railway	Brazil	170/88
South African Railways	South Africa	175/93 and 185/103
South Indian Railway	India	171/89
South West African Railways	South West Africa	173/91 and 186/104
South Manchuria (Railway)	China	174/92 and 178/96
Ulster Railway	Ireland	168/86
Uniao Valenciana (Railway)	Brazil	170/88 and 194/112
National Light Railways	Belgium	172/90
Vassourense (Railway)	Brazil	170/88 and 194/112
West Cornwal Railway	England	183/101
Ytuana (Railway)	Brazil	170/88 and 194/112

CHAPTER XI. — *A*) ABSORPTION OF A LINE BY A RAILWAY WHICH ALREADY POSSESSES AN IMPORTANT SYSTEM LAID TO ANOTHER GAUGE.

It frequently happens that a railway absorps an isolated line or a smaller railway system. When these are in the same district one aims at unifying the structural conditions and also the rolling stock, and if the line which is taken over is of another gauge, the possibility of conversion will be investigated so as to make it conform with the general system. As this almost always requires the purchase of stationary plant and rolling stock, this radical solution is often preferable. One will only retain the original gauge if the traffic which may be anticipated is very small, and where the reloading at the connecting station is of relatively small importance.

We give below some examples of gauge conversions of this kind which have been carried out, these being grouped according to continent and country in the usual order :

1. — Europe.

Belgium. — The railways have nearly always been laid to the standard gauge, there being only two exceptions.

The *Pays-de-Waes Railway* had a gauge of 1 m. 10 (3′ 7 1/4″). This was increased to 1 m. 435 (4′ 8 1/2″) when the railway was taken over by the State.

The *Noville-Taviers-Embresin Railway*, a secondary line of 10 km. (6.21 miles) in length, laid to a gauge of 0 m. 717 (2′ 4 1/4″), was destroyed, as were many others during the German occupation. This will probably be reconstructed to 1 m. (3′ 3 3/8″) gauge, which is the usual gauge for secondary lines in Belgium.

France. — The *Sceaux Railway* was provided with special rolling stock of the Arnoux system. When this was taken over by the *Orleans Company*, the gauge was altered from 1 m. 75 to 1 m. 45 (5′ 8 7/8″ to 4′ 9″), and at the same time the other structural conditions were standardised. The line in its reconstructed condition was opened for traffic on the 22 May 1891.

Ireland. — The *Great Northern Railway* was formed by the amalgamation of four railways. One of these, the *Ulster Railway* had been constructed in 1836 to a gauge of 6′ 2″. It was relaid to the usual gauge of 5′ 3″ after its incorporation in the new system.

On the other hand, various sections have been converted from the 5′ 3″, which is that in general use on the system, to the gauge of 3′, which is that of a certain number of railways in the mountainous part of the country, in the cases where no very considerable traffic was anticipated. The reduction of gauge carried out under these conditions was not a very costly matter [1].

2. — Africa.

In certain colonies, lines are laid to a very narrow gauge for reasons of economy. At a later date, when the general system is developed, the gauge of these original lines is increased. This has

[1] This for example was done in the case of the *Finn Valley Railway* (from Strabane to Stranorlar) after its amalgamation with the *West Donegal Railway*, to form, in 1892, the *County Donegal Railway*. This conversion took place in July 1894.

This was also done on the 29 October 1903 on the Cork and Passage section of the *Cork Blackrock & Passage Railway*.

been the case in Lagos, Mozambique and Togo.

TOGO. — The *Togo Coast Railway*, from Lome, to Anecho, 44 km. (27.34 miles) in length laid to the gauge of 0 m. 75 (2′ 5 1/2″). This was increased to 1 m. (3′ 3 3/8″) when the remainder of the system was constructed.

The COLONY OF LAGOS has a railway system 1 402 km. (871 miles) in length of 3′ 6″ gauge. The *Bauchi line*, 142 km. (88 miles) in length, which forms part of the above, was constructed between 1910 and 1912 from Zaria to Rahama, had a gauge of 2′ 6″, the cost being £1 977 per mile. In order to bring this into line with the remainder of the system, this was converted in 1913 to the general gauge of 3′ 6″ and has since been extended.

MOZAMBIQUE. — The *Beira Railway* was constructed with English capital from Fontesville, a port situated on the River Pungwe to Umtali situated on the Rhodesian Frontier. The *Beira Junction Railway* connected the town of Beira to Fontesville by means of a railway 35 miles in length of 3′ 6″ gauge.

The *Beira Railway* constructed its line of 187 miles to a gauge of 2′ 1 1/2″ and with gradients of 1 in 50 and curves 5 chains radius at a cost of £5 235 per mile.

However, the Rhodesian railways which form a prolongation of this railway were of 3′ 6″ gauge, as are those in South Africa. It was quickly realised that a mistake had been made in constructing the *Beira Railway* to a 2′ 1 1/2″ gauge, and it was relaid to the gauge of 3′ 6″. This allowed the railways to join up, and the cost for 169 miles was £3 321 per mile. The cost of 77 000 fr. per kilometre for the original line of 2′ 1 1/2″ gauge was thus brought to a total of 145 000 fr. per kilometre for the reconstructed line.

3. — America.

IN THE ARGENTINE, the only gauge modification has been that of the little *Maleguano Railway* when this was amalgamated with the *Central Argentine Railway*. Its 60 km. (37 miles) of line were converted from 2′ 5 1/2″ to 5′ 6″ in 1911.

NORTH EAST ARGENTINE RAILWAY. — The first line of this system which was to have been constructed to broad gauge was sanctioned by the Argentine Government on the 11 October 1864, and was conceded to the *East Argentine Railway*. However, before works were put in hand, the gauge was reduced to the normal gauge, which was that in use on the *Entre Rios Railway* with which it connected.

BRAZIL. — In contrast to what has been done in the Argentine, a large number of isolated lines which have no points of contact with one another have been constructed in Brazil, and these have very different gauges.

The policy followed since then has been towards a unification of the systems. In order to carry this out, a number of these lines have been bought up and the gauges of these have been unified. See particulars given in table 51.

CHILI. — The *Antofagasta & Bolivia Railway Company*, whose lines in Chili are laid to the gauge of 2′ 6″, took over, in 1906, the branch line to *Chonchi Viejo*, 19 km. (11.8 miles) in length, of which the gauge was 0 m. 50 (1′ 7 11/16″) and this is now being converted to 2′ 6″.

The various Chilian railways, which are now incorporated in the State system, have also been converted where the gauge differed from the normal gauges of the

Table 51.

Gauge conversions of the various Brazilian Railways.

LIGNES.	Length in kilometres	Gauge original.	Gauge new.	Present name.	Date of conversion.
Ribeirao Barreiros	57	2′ 6″	Metre.	Great Western Railway.	1912-13
Recife-Sao Francisco	125	1 m. 60	—	— — —	1905
Bahia-Sao Francisco	123	1 m. 60	—	Bahia.	1911
Bahia Central	318	1 m. 067	—	—	1912-13
Penha Branch	6	0 m. 80	—	Rio do Ouro.	...
Porto Novo Branch	64	1 m. 60	—	Fluminense.	1911
Uniao Valenciana	63	1 m. 10	—	—	1913
Vassourense	6	0 m. 60	—	—	1912
Catazagues S. Antonio. . . .	48	0 m. 60	—	Leopoldina Railway.	...
Old Maua Railway.	16	1 m. 67	—	— —	1882
Nichteroy Cachoeiras	73	1 m. 60	—	— —	...
Crchoeiras Macuco.	107	1 m. 10	—	— —	...
Porto das Caixas Macahe. . .	146	1 m. 10	—	— —	...
Cordiero Portella	78	1 m. 10	—	— —	...
Barao de Araruama	40	0 m. 65	—	— —	1890
Imbetiba Campos	96	0 m. 95	—	— —	...
Old Ytuana System	220	0 m. 96	—	Sorocabana Railway.	1892-94
Funilense.	41	0 m. 60	—	Sao Paulo State.	...
S. Paulo Queluz.	260	1 m.	—	Central of Brazil.	...

latter, which are 5′ 6″ and 1 m. (3′ 3 3/8″) (1).

In the same way, the construction of the *Chilian Longitudinal Railway* to the gauge of 1 m. has led to a reduction in the gauge of several branches of the *Central State Railway* from 5′ 6″ to 1 m., and will lead to the compulsory conversion to the gauge of 1 m. of a number of lines belonging to independent companies which connect this to the sea coast.

(1) Thus the *Chanaral Pueblo Hundido* section (64 km. or 39.76 miles) and the *Inca de Oro* branch (54 km. or 33.55 miles) were converted from 3′ 6″ to 1 m. after being taken over by the State in 1904.

The same is being done on the line from *Serena Coquimbo* and *Ovalle,* of which 93 km. (57.78 miles were built by a company to a gauge of 5′ 6″, and were reduced by the State to 1 m. in 1910.

The *Tongoy Railway* (64 km.) laid to the gauge of 3′ 6″ was reduced to 1 m. in 1912.

4. — Asia.

British India. — As is well known, railways in India are laid to two principal gauges, namely, the 5′ 6″ and the 1 m. gauge. As the lines have not been constructed to any general plan, there has been a certain amount of relaying, this most often taking place when railways of lesser importance have been absorbed, and sometimes also by dividing up a line which is in a bad financial state so that the sections may be taken over by companies in a more prosperous

condition (1). In either case this often leads to a change in gauge in order to make certain sections uniform with the neighbouring system.

Table 52, which is taken from the Government's Report for 1913-14, gives as complete a list as we have been able to obtain. One will notice that there

TABLE 52.

Gauge conversions on Indian Railways.

SECTIONS (2).	COMPANY.	Length. Miles.	Length. Kilo-metres.	Date opened.	Original gauge.	Re-opened.	New gauge.
Raj Nandgaon Nagpur	Bengal-Nagpur.	145	233	1880-81-82	1 m.	27.11.88	1 m. 67
Viramgam Wadwhan	Bombay-Baroda & Central India.	39	63	25.5.72	1 m. 67	14.12.02	1 m.
Kaunia Mogalhat	Eastern Bengal.	18	29	6.2.82	2′ 6″	1.4.07	1 m.
Cooch Behar Railway	— —	33	53	1891-1900	2′ 6″	1910	1 m.
Sadutrabari extension	— —	18	29	1900-1901	2′ 6″	1910-1911	1 m.
Deoghur branch	East Indian.	4	6	23.12.82	1 m.	13.9.13	1 m. 67
Gudur to Nellore	Madras & Southern Mahratta.	24	39	1.11.88	1 m.	1.11.99	1 m. 67
Bellari Guntakal	— —	30	48	1871	1 m. 67	16.5.87	1 m.
Lahore Jhelum	North Western.	103	165	9.1873	1 m.	6.10.78	1 m. 67
Lala Musa Malakwal	(Military) North Western.	45	72	10.4.80	1 m.	10.2.86	1 m. 67
Khushalgarh Kohat	North Western.	33	53	25.5.02	2′ 6″	5.1.08	1 m. 67
Bhera branch	— —	18	29	1880-1882	1 m.	15.3.87	1 m. 67
Dandot branch	— —	9	15	1.1.83	1 m.	1887-1889	1 m. 67
Hyderabad	Jodhpur Bikanar.	55	89	16.8.92	1 m. 67	20.10.01	1 m.
Wadwhan Rajkot Junction.	Morvi.	74	119	...	2′ 6″	4.7.05	1 m.

(1) This was recently the case as regards the *East Coast Railway*, and also the *Madras Railway*.

(2) The line from Nagasatam to Erode on the *Great Southern Railway* (513 km. or 319 miles) was opened in 1859 (267 km. or 166 miles). The gauge was reduced to 1 m. on its amalgamation with the *South Indian Railway* and this took place from June to December 1879.

Only 28 km. (17.4 miles) of the *Carnatic Railway* (Tandore Cuddalore) had been opened for traffic when it was taken over by the South Indian Railway in 1877. Its gauge was converted to 1 m. (3′ 3 3/8″) and it was extended with this new gauge as far as Porto-Novo.

When the *Eastern Bengal State Railway* absorbed the *Cooch Behar State Railway* the latter had a gauge of 2′ 6″. The 33 miles of this railway were opened 1893 to 1898. They were converted to the 1 m. gauge in 1910.

The first section of the *Bengal Nagpur Railway*, 144 miles in length, to the gauge of 1 m., was converted to the broad gauge and re-opened 27 November 1888. The first section constructed to the broad gauge dates from 1886. This was the 36 miles between Umarra-Katua.

The *Punjab Northern Railway* from Lahore to Jhelum, opened with the gauge of 1 m. in 1873, was converted to broad gauge five years later. The same was done in the case of the *Indus Valley Railway* from Lahore to Rohri, which was partially constructed to the 1 m. gauge and subsequently increased.

are a certain number of 2′ 6″ gauge lines which have had the gauge increased to 1 m. and even to 1 m. 67 (5′ 6″). These are light railways which it has been subsequently found necessary to replace with ordinary lines.

In order to obtain a complete account, one should also see the table of cases in which a third rail has been laid so as to allow trains of both gauges to be run.

Some locomotives on these railways underwent some very strange alterations to enable them to be used after the alteration in the gauge had taken place (1).

JAPAN. — The main railway system is laid to the gauge of 3′ 6″, but there are secondary lines belonging to companies, not only of the 3′ 6″ gauge, but also of gauges of 2′ 6″, 2′ 4″ and 2′.

One of the 2′ 6″ lines, the Ishimaki line, 28 km. (17.4 miles) in length, was absorbed by the main system and the gauge converted to 3′ 6″ in August 1920.

CHAPTER XII. — *B*) RECONSTRUCTION OF A RAILWAY UNDER DIFFERENT STRUCTURAL CONDITIONS.

The most frequent cases of this kind are lines which have been hastily constructed to meet the needs of the moment. It may be that subsequently these are of no further use and they are then dismantled, but it may happen, however, that these fulfil a commercial need, and that it is necessary to strengthen them. Their original construction may only fit them for traffic for a limited period, and as a rule it is necessary to strengthen and reconstruct such lines, especially in the case of railways which were built in the first place for purely stragetic reasons.

In order te secure speed in construction, these lines may have been laid to a very narrow gauge under very indifferent conditions. If it is subsequently found that the line is still useful, it is often relaid to a broader gauge. We give below a series of examples, grouped according to continents and countries.

1. — **Europe.**

BELGIUM. — *National Light Railways Company,* owned before the war more than 4 000 km. (2 500 miles) of secondary railways, of which 13 lines (about 510 km. or 317 miles), in the Province of Antwerp, were of the same gauge as the Dutch lines (1 m. 067 [3′ 6″]), three lines were of standard gauge, while the remainder were of 1 m. (3′ 3 3/8″) gauge.

Three-quarters of the system was destroyed during the war, including 347 km. (215 miles) of 1 m. 067 gauge. The opportunity was taken after the Armistice to reconstruct these to the gen-

(1) In this way some 0-4-0 tender locomotives, built in 1870 by Hunslet Company of Leeds for the *Oudth & Rohilkund Railway,* were sold after some years to a canal company which altered these to the 1 m. gauge. Being brought back in 1892 for the Godavery branch, they were converted in the Waltair workshops of the *Oriental Coast Railway* to the gauge of 5′ 6″. This latter railway having been taken over in 1901 by the *Bengal-Nagpur Railway,* these engines were reconverted and made suitable for the 2′ 6″ gauge. These locomotives were again rebuilt in 1908 at the Kbargpur workshops and sold the *Bankura-Damoodar Railway* of 2′ 6″ gauge, where they are still running. (See *The Locomotive Magazine* for January 1917.)

eral gauge of 1 m., and the 163 km. (101 miles) of 1 m. 067 gauge line, which was still intact, is also being converted into the same gauge.

The *Noville-Taviers to Embresin Railway* is in the same category. It is 10 km. (6.21 miles) in length, and was laid to the gauge of 0 m. 717 (2′ 4 1/4″). It was destroyed by the Germans, as were the majority of the light railways. Reconstruction had not commenced on the 31 December 1922. It will most probably be relaid to the 1 m. gauge.

Bosnia-Herzegovina. — After the occupation of this mountainous country by Austria-Hungary, a remarkable railway system with a gauge of 2′ 6″ (0 m. 76) was very rapidly constructed. Up to the present it has proved sufficient for all traffic requirements. It has only been necessary to strengthen the track, but there has been no necessity to reconstruct the lines. It it apparent, however, that in the more or less distant future it will be converted to a broader gauge.

2. — Africa.

South West Africa (fig. 17). — In 1897, the cattle plague rendered transport very difficult, and the German military engineers constructed a light railway 382 km. (237 miles) in length from the port of Swakopmund to Karibib and Windhoek. This was completed in June 1902. It was laid with rails 5 m. (16′ 4″) in length weighing 9.5 kgr. per metre (19.15 lb. per yard), the total weight of the superstructure being 38 kgr. per metre (76.6 lb. per yard). Gradients were as much as 1 in 20, while the radius of the curves in some cases were as small as 60 m. (3 chains). The cost of construction was 500 000 fr. per kilometre.

In 1910, the colony took over the Otavi Railway. It was doubled from the coast as far as Karibib, and then the conversion of the gauge to 3′ 6″ was undertaken on 188 km. (116 miles) from Karibib to Windhoek. This was laid with 20 kgr. (40.32 lb. per yard) rails carried on ten metal sleepers weighing 30 kgr. (60.47 lb.); the reconstruction being finished on the 1 April 1913 at a cost of 70 000 fr. per kilometre.

Fig. 17. — Map of lines in South West Africa.

Explanation:
- ——— 0 m. 60 (2′) gauge.
- ━━━ 3′ 6″ gauge.
- ═ ═ ═ 0 m. 60 gauge converted to 3′ 6″ gauge.
- -x-x-x Frontier.

The war led to another conversion of the same order. The British troops penetrated into German South West Africa both from Cape Colony and from Walvis Bay. After having constructed a short length of railway (20 miles [32 km.] in length) to the gauge of 3′ 6″ from this place to the terminus of the German line at Swakopmund, they increased the gauge of the latter as far as Karibib, thus ob-

taining a continuity of gauge from Walvis Bay (via Windhoek) and onward to Cape Colony. There only remains the section of 2′ gauge from Rossing to Karibib, which was demolished after the war.

3. — America.

No example.

4. — Asia.

CHINA. — Some of the *South Manchurian Railways* which were in existence before the Russo-Japanese war were laid to the 5′ gauge. As these were destroyed by the Russians, they were reconstructed by the Japanese who adopted the gauge of 3′ 6″ so that they could employ their rolling stock. When the war was finished, it was necessary to reconstruct these railways in the most suitable way, and it was decided at the same time to increase their capacity. For this reason the 4′ 8 1/2″ gauge was adopted, which is the same as that in the neighbouring Chinese railways.

The principal section, 696 km. (432.5 miles) in length, of the *Dairen to Changhun* line, and 160 km. (100 miles) of branch lines were converted, or rather reconstructed between April 1907, the time when they were taken over, and October 1909, the time when the main line was doubled.

The *Angtung-Mukden Railway*, 339 km. (211 miles) in length, was hastily constructed by the Japanese in 1905-1906, and in order to expedite the work, it was laid to the gauge of 2′ 6″, using rails, 12 1/2 kgr. (25.19 lb. per yard), taken from the Russians, and with odd rails, the weight of which varied up to 20 kgr. (40.32 lb. per yard). The maximum gradients were 1 in 30, and the sharpest curves of 2 chains (40 m.) radius. After the war it was decided to reconstruct this line which connected Coree to the Manchurian Railway, and it was laid to the gauge of 4′ 8 1/2″. The reconstruction took place between August 1909 and the 3 November 1911. The maximum gradients for the reconstructed line were 1 in 80, and the minimum radius of curves 300 m. (15 chains). In spite of this, the new line, which is 305 km. (189.5 miles) in length, is 44 km. (27 miles) shorter than the original line.

TURKEY IN ASIA. — The case of the *Bagdad Railway* is typical. It was first built in 1871 by an English company to the gauge of 3′ 7 1/4″ (1 m. 10) from Haidar Pacha to Ismid.

When the line was taken over by the Porte in view of its future extension, this was not suitable for a line which was to become the first section of a railway of the importance of the line to Bagdad (which is situated 2 430 km. or 1 510 miles from Haidar Pacha) and it was converted to standard gauge.

CHAPTER XIII. — *C*) RECONSTRUCTION OF A RAILWAY WHICH HAS REACHED ITS MAXIMUM CAPACITY.

When a railway has been laid to a narrow gauge, and the traffic requirements make it necessary to increase its capacity, one may resort to the following methods :

A) Strengthening of the track so as to allow the use of more powerful engines so that heavier trains may be run, and a greater volume of traffic handled;

B) Doubling the line;

C) Conversion of the gauge.

The first case does not come within

the scope of this article. However, if it is necessary to still further increase the capacity of the line, one may either double the line or convert the gauge; the choice being governed by the particular circumstances. As a rule it is better to adopt the more radical method, which consists of changing the gauge, provided that this is not a departure from the gauge usually employed in the particular country. In such a case one should consider whether a general conversion is necessary. In this way the Rio suburban lines of the *Leopoldina Railway*, which is of the 1 m. gauge, have been doubled, as has also been done in the case of certain railways in South Africa which are of the 3′ 6″ gauge. In both cases these sections form part of a large system which is laid throughout to the same gauge.

On the other hand we give below a certain number of cases where the conversion of gauge has been undertaken, and we have grouped these according to country in the usual order.

1. — **Europe**

No example.

2. — **Africa**.

BELGIAN CONGO. — The *Congo Railway* was laid to the gauge of 0 m. 765 (2′ 6 1/8″) (1). As the traffic grew, it was decided to increase the capacity in three successive stages. The first of these consisted of introducing more powerful motive power, and this is in use at the present time. The second consisted in reconstructing part of the line with a stronger track so as to allow trains of greater tonnage, and this measure has just been put into execution. Finally, in the near future, when the traffic has grown still further, it will be necessary to increase the gauge itself. It is most probable that a gauge of 1 m. 067 (3′ 6″) will be adopted.

(1) The rolling stock is designed for a gauge of 0 m. 75. The width of the track corresponds to the maximum overhang on curves so that metal sleepers of only one type may be employed.

3. — **America**.

CHILI AND BOLIVIA. — *Antofagasta (Chili) and Bolivia Railway* (fig. 18). — The main line of this railway runs from Antofagasta to Bolivia, climbing through the Cordillera mountains in order to reach plateaux of more than 4 000 m. (13 130 feet) altitude. It then proceeds to La Paz without meeting any very difficult country. The principal section from Antofagasta to Uyuni was constructed to the gauge of 2′ 6″, and the 545 km. (338 miles) from Uyuni to La Paz to the gauge of 1 m.

There is a considerable export mineral traffic, and thus the 2′ 6″ line carries very heavy traffic. For this reason it has for a long time been realised that it is necessary to increase its capacity. This could have been done in two ways : either by doubling the line or by increasing the gauge. The latter solution has been adopted, and work has been put in hand to convert the greater part of the railway which is situated in the high plateaux of Bolivia to the gauge of 1 m. The section which has been converted is 313 km. (194 1/2 miles) in length situated between Oruro and Uyuni, which was dealt with as follows :

For the first 60 km. (37 miles) after leaving Oruro, the 36 lb. rails were replaced by rails of 65 lb. to the yard, and a third was laid to the gauge of 1 m. On the other hand, for the remaining 253 km. (157 miles) towards Uyuni, two new lines of rails were laid to the gauge of 1 m. on either side of the existing 36 lb. rails.

Fig. 18. — Antofagasta (Bolivia) Railway.

EXPLANATION :
- ——— 2′ 6″ gauge.
- ━━━ 1 m. 00 (3′ 3 3/8″) gauge.
- ═══ Mixed gauge.
- - - - - 2′ 6″ gauge converted to 1 m. gauge.
- -x-x-x Frontier.

The work was finished as far as the Rio Mulato in February 1912, but the new line has only been in use since the 10 February 1916 when the section from Oruro to Uyuni was completed. The third rail of the narrow gauge on the first section and the two additional 36 lb. rails on the second section have been taken up.

In this way at the present time there is a continuous line of 2′ 6″ gauge from Antofagasta to Uyuni, and a 1 m. gauge from that place on to La Paz. The branch lines of the first portion are also to a gauge of 2′ 6″, while those on the second section are of 1 m. gauge.

It may be noticed, however, that the *Antofagasta Company* operates the *North Chilian Railway*, which is of the 1 m. gauge and which connects with its 2′ 6″ line, and in order to ensure continuity of traffic, a third rail of 1 m. gauge has been laid from Antofagasta to Bodequeno, which is the connecting point with the North Chilian Railway.

BRAZIL. — The *Western of Minas Railway*, which is owned by the State, has an important system laid to the gauge of 1 m., and also another line of 0 m. 76 (2′ 6″) gauge which was constructed to deal with a less important traffic (fig. 19). The traffic having increased and with a greater amount of interchange traffic taking place with the neighbouring system, steps were taken as a transitory measure to lay a third rail over certain sections. The situation as at the 1 January 1921 was as follows :

TABLE 53.

WESTERN OF MINAS RAILWAY.	Open for traffic.	Under construction.	Surveyed.	Total.
1 m. gauge	1 182	257	74	1 513
0 m. 76 gauge.	723	42	...	765
Mixed gauge	15	...	...	15
	1 920	299	74	2 293

Fig. 19. — Map of the Western of Minas Railway (Brazil).

Explanation: 1 m. 60 (5′ 3″) gauge. 1 m. (3′ 3 3/8″) gauge. 0 m. 76 (2′ 6″) gauge. Mixed gauge.

The 0 m. 76 (2′ 6″) line having nearly reached its maximum capacity under its present structural conditions, it is intended to increase the gauge to 1 m. rather than to merely lay heavier rails.

UNITED STATES. — At one time the 3′ gauge was largely favoured and thousands of miles were constructed. At this time there was also a large number of lines of broader gauges and a general standardisation was decided upon. This work was mainly carried out in 1886, when six of the broad gauges were abandoned in order to adopt the standard gauge of 4′ 8 1/2″. On account of the feeling in favour of this gauge, steps were taken to widen about 5 000 miles of the 3′ gauge; the most important part of this belonged to the *Denver & Rio Grande Railway*, which had about 2 500 miles open for traffic. About 1 200 miles were then converted from the 3′ gauge, and the remainder of the work was done gradually. The last section of *Marshall's Pass*, which is 236 miles long, was converted in 1912. It rises to an altitude of more than 10 000′ and includes gradients of 1 in 26 and curves of 46 m. (2.3 chains) radius. The cost of conversion per mile was estimated at $8 500, which at that time was about 27 000 fr. per kilometre.

MEXICO. — The *Mexican National Railway* 1 200 miles long, was constructed to the gauge of 3′, but was not able to compete with the *Mexican Central Railway* and the *International Railway*. It was converted to standard gauge from 1902 to 1904.

4. — Asia

CHINA. — We have referred to the reconstruction of the *Angtung-Mukden Railway*, which was changed from 2′ 6″ to 4′ 8 1/2″ in order to meet traffic requirements.

The *South Manchurian Railways*, which were hastily constructed by the Japanese to a 3′ 6″ gauge after their destruction by the Russians during the Russo-Japanese war, were afterwards converted to the 4′ 8 1/2″ gauge so as to increase their capacity and also to bring them into line with the Chinese system.

BRITISH INDIA. — About 1863, the *Indian Branch Railway* was constructed with a gauge of 4′ (1 m. 22). From the time of opening, the traffic was heavy, and after three years it was converted to the broad gauge of 5′ 6″ which is used by the other principal lines in India.

However, cheaper lines were still laid to the 1 m. gauge, and also light railways to the gauges of 2′ 6″ or 0 m. 60 (2′).

Some of these, which subsequently became more important, were reconstructed to a broader gauge and absorbed into the general system.

One will find in the list given in table 52 the lines of British India which have had the gauge converted.

CHAPTER XIV. — *D*) ALTERATION OF GAUGE FOR REASONS OF ECONOMY.

The above heading may at first sight appear paradoxical, since if a line is in financial difficulties and it is necessary to resort to drastic measures, it does not appear to be desirable to commence by the expenditure of relatively large sums of money in order to convert the gauge. It would seem rather that this money might be

otherwise better employed. This, however, is not always the case, as will be shown by some of the following examples.

Some overseas countries and colonies commenced their railway construction by using the same gauge as is in use in the home country, or sometimes a still larger gauge. They may find that after a short time has elapsed that they cannot continue on these lines, as they are only able to construct an insufficient mileage, whereas it is indispensable in order to develop the country, to extend the railway as far as possible into the interior. They have then adopted a narrower gauge for the remainder of the system, and have converted to this new gauge the sections which were already made. This has been the case in the following examples :

TABLE 54.

COUNTRY.	Gauge of original sections.	Gauge of the general system to which these original sections have been converted.
Cape Colony	1 m. 435	1 m. 067
Natal.	1 m. 435	1 m. 067
Tasmania	1 m. 60	1 m. 067
New Zealand :		
North Island	1 m. 67	1 m. 067
South Island	1 m. 435	1 m. 067
Brazil :		
Leopoldina Railway	1 m. 67	1 m.
Great Western Railway.	1 m. 60	1 m.

1. — Europe.

ENGLAND. — The *Eskdale & Ravenglass Railway*, which is 7 miles in length, was constructed to the gauge of 2′ 9″. As the line did not pay, it was closed to traffic. The *Narrow Gauge Railways Limited* purchased the line and reduced it to a still smaller gauge. At the present day it is the narrowest gauge in the world, as the rails are only 1′ 3″ apart between their inside faces. Reopened for traffic in 1915, it became a paying concern because the cost of working is very small, and it became of interest as a curiosity. It fulfils all the needs both as regards passenger and freight traffic.

2. — America.

BARBADOS [1]. — Another interesting example of a gauge conversion for economical reasons is that of the *Barbados Railway*, which was carried out by Mr. Calthrop.

Constructed to the gauge of 3′ 6″, it was worked at a loss and became in a deplorable state of repair, the engines being too heavy for the track. Instead of relaying this in its original condition, it was reconstructed to the gauge of 2′ 6″ on similar lines to the *Barsi Light Railway*, all the rolling stock having an axle

(1) Information kindly supplied by Mr. Calthrop.

load of 5 t. It was found that the capacity of the railway was tripled.

Some rolling stock was converted by bringing the wheels closer together and substituting central couplings at a height of 1′ 9 1/2″ from the rails in place of the side buffers 2′ 6″ from the rail, which have led to derailments.

PARAGUAY. — The *Paraguay Central Railway* was constructed to a gauge of 5′ 3″. Since the time of its construction, certain financial groups combined their interests with that of certain Argentine Railways which separated it from Buenos-Ayres. The *Central Buenos-Ayres,* the *Entre Rios,* and the *North East Argentine Railways* were of the standard gauge of 1 m. 435 (4′ 8 1/2″), and these gave direct communication between Buenos-Ayres and the frontier of Paraguay at a point close to the terminus of the only railway in that country. For this reason it was decided to convert it to the same gauge of 4′ 8 1/2″ so as to allow uninterrupted traffic between Paraguay and Buenos-Ayres without reloading. The reduction of gauge of this line, which is 373 km. (232 miles) in length, was carried out in 1911-1912. The rolling stock was bought by the Argentine Government, who used it on the construction of a broad gauge line in Patagonia.

CHAPTER XV. — *E*) STANDARDISATION OF GAUGE OF TWO LINES OR SECTIONS OF LINES.

When independent lines are called upon to deal with through traffic which may subsequently arise, it is often necessary to standardise their gauges. The following are some examples.

1. — America.

BRAZIL. — The ***Ribeirao Bonito to Ibitinga Railway*** of the Dourando Company, in Brazil, which is 144 km. (95.5 miles) in length, was converted from 0 m. 60 to 1 m. (1′ 11 5/8″ to 3′ 3 3/8″) gauge in 1913.

The line from *Porto Neves to Marica* (Marica Railway) was converted from 0 m. 75 to 1 m. (2′ 5 1/2″ to 3′ 3 3/8″) (1912-1913). The length of this line is 61 km. (38 miles).

2. — Asia

MESOPOTAMIA (1). — At the present time there are 945 miles (1 521 km.) of railway in Mesopotamia, whereas there were 1 113 miles (1 791 km.) during the war.

There has been a diversity of opinion whether the standard gauge or 1 m. (3′ 3 3/8″) gauge should be adopted for the whole of the system, and this question has had an influence in the construction of the line from Basra to Bagdad, 325 miles (523 km.) in length.

The first line which was constructed in Mesopotamia to the gauge of 1 m. was that from *Basra to Nasrieh* along the banks of the Euphrates, 140 miles (225 km.) in length. This was laid with 75 lb. rails carried on 1 600 sleepers per kilometre (2 575 sleepers per mile). This subsequently became the first section of the Basra to Bagdad line.

It was intended to eventually convert this to standard gauge, and suitable sleepers were therefore used and the rails were laid in such a way that if one the rails was removed to a distance of 1 m. 435 (4′ 8 1/2″) from the other, the line, as

(1) See *The Railway Gazette* for the 30 January 1920.

altered, would be carried symmetrically on the sleepers.

The second section, which is from *Nasrieh* to *Hillah*, was constructed to the 1 m. gauge. The third section from *Hillah* to *Bagdad* was of the standard gauge. This was converted to 1 m. gauge in order to allow through traffic.

CHAPTER XVI. — *F*) GENERAL STANDARDISATION OF THE GAUGES IN ONE COUNTRY OR TERRITORY.

1. — Europe.

The most important case which may present itself as regards railway gauges is their standardisation in any particular country.

We shall give, as we have already done for other cases of conversion, general information upon standardisation of this kind which has been carried out in the past, so as to afford information which may be useful in cases which are under contemplation at the present time.

As regards main lines, it is only necessary to mention what has been done in Germany, England, South Africa, the United States and New Zealand, and in several other countries which have had railways for a considerable time and which have adopted a standard gauge. The same question, however, may arise in countries which have not as yet standardised the gauge of their system. In such cases one meets with a number of gauges, and the problem is an important one which increases in magnitude each year the solution is delayed. In some countries it has already reached an acute stage, and therefore we will deal more fully with the case of the Argentine, Australia, Brazil and British India.

The second case is that of certain countries which, having adopted their own standard gauge, remain isolated from the general railway system, and therefore suffer a certain amount of inconvenience. For this reason we will consider the possibility of the substitution of the standard gauge for the Spanish gauge of 1 m. 67 (5′ 5 3/4″).

The third case of general standardisation arises in those countries which have an important railway system which has almost reached its maximum capacity, and where it is considered advisable to adopt in the near future a larger gauge rather than to construct new lines of a limited capacity. This is the case in Japan.

We will examine in this way the situation in each of the countries mentioned, and we will take these according to continent and country [1].

(1) The list is a follows :

Continent.	Country.
1. Europe	Germany.
	England.
	Spain.
	Holland.
	Poland.
2. Africa	South Africa.
	Belgian Congo.
3. America	Argentine.
	Brazil.
	Canada.
	United States.
4. Asia	British India.
	Palestine.
5. Oceania	Australia.
	New Zealand.

GERMANY. — Certain lines were originally constructed to the broad gauge. A conference decided on the adoption of the standard gauge. The *Baden State Railways*, which were laid to a gauge of 6 Badish feet (1 m. 80), were altered to 1 m. 435 (4′ 8 1/2″).

No great inconvenience, however, was caused from the fact that the Baden railways, and those of Holland, were laid to different gauges, because the stream of international traffic did not pass through these two countries.

ENGLAND. — In the early days of railway construction these were built radiating from London into the country.

The first railway was of 4′ 8 1/2″ gauge, but many engineers preferred other gauges. In this way, Mr. Braithwaite, chief engineer of the *Eastern Countries Railways*, which was the nucleus of the *Great Eastern Railway*, chose a broader gauge so as to give more space for the accomodation of the moving parts of the locomotive. This argument was more sound than was the method of putting it into operation, since the increase of gauge which was adopted was almost insignificant. The gauge of this railway, which was laid to Chelmsford and Cambridge, was in fact only 5′.

Mr. Brunel, who built the *Great Western Railway*, decided on a gauge of 7′, and thought thereby to obtain greater capacity and a better stability, which would thereby alow very much higher speeds to be attained than on other railways, and in this he succeeded. It is a remarkable fact that as far back as 1846 the timetable allowed 57 minutes for a run of 53 miles (85 km.) between London and Didcot, including a start from rest at Didcot [1].

Up to a point, no great inconvenience was experienced but this ceased to be the case when for the first time two lines of a different gauge met. This took place at Gloucester where the *Midland Railway*, of standard gauge, and the *Great Western*, of broad gauge, ran into the same station. It was then that the public found for the first time the inconvenience due to transhipment, which was aggravated by the fact that it took place between trains of rival companies.

The « battle of the gauges » raged in England from the year 1845 onwards, and terminated by the defeat of the broad gauge. It was in vain that Mr. Brunel attempted to overcome the difficulty by adopting special means of transhipping. He built at Paddington Station hydraulic aparatus capable of lifting the bodies of broad gauge wagons in order to place these on standard gauge underframes. With the same object in view, he built rolling stock which could run equally well on lines of either gauge, but despite these efforts, he had to give up the struggle.

Already at this time Stephenson had decided that the *Eastern Counties Railway* should construct its extensions to standard gauge and convert its existing lines to the same [1].

It may be noted as illustrating the common interest between standard gauge railways, that the *London & North Western Railway* allowed *Midland Railway* trains to use *New Street Station*, Birmingham, for a nominal annual sum of £100 only.

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[1] This run was frequently done in 47 1/2 to 50 minutes, that is to say, at an average speed which has not since been exceeded. It is even stated that a tender engine belonging to the same company attained a speed of 80 miles (129 km.) an hour on a broad gauge railway from Bristol to Exeter. (See ACWORTH : *The Railways of England*.)

[1] These were relaid to the 4′ 8 1/2″ gauge between August and October 1844.

At this time it was decided to abandon the broad gauge on the *Great Western Railway*. The *Gauge Regulation Act* of 1846 did not compel the majority of the lines of this Company, or of the subsidiary companies, such as the *South Wales Railway* to comply with its regulations, but it was realised that they would have to fall into line. The various broad gauge lines were therefore one after another converted to standard gauge. As a transitory measure, those which still remained were provided with third rails.

In 1868, the first section, 7 miles in length, from Princes Risborough to Aylesbury, was converted to standard gauge. Other sections were successively dealt with (1) so that in 1890 there were only 426 miles of broad gauge, of which 153 miles were laid with a third rail, out of a total of 2 500 miles. The principal remaining section of broad gauge was that between Exeter and Truro, although the branch lines of this section had been laid to the standard gauge. The bodies of the carriages were made to the ordinary loading gauge so that they could later be utilised on standard gauge underframes. In the same way new broad gauge engines with inside frames could be converted in two days into standard gauge engines with outside frames.

When the viaducts on the single line broad gauge sections were reconstructed, provision was made for a double line of standard line. The last broad gauge section of the *Great Western Railway* was converted in 1892.

Two of the lines belonging to the *Great* section of the *Great Western Railway* cessive changes of gauge, one of these, the *West Cornwall Railway*, which runs from Hayle on the North coast to Newham on the River Fal close to Truro, was constructed in the first place to standard gauge. Brunel increased this to the 7′ (2 m. 13), but it was later again reconverted. The other one, the *Gloucester to Cheltenham Railway*, was similarly dealt with. Originally a standard gauge line, it was converted to a third rail line, but was subsequently reconverted to standard gauge (1).

The *Metropolitan Railway Company* was very closely connected with the *Great Western Railway*. It was projected on the 7 August 1854 for the purpose of providing an underground railway in London with three rails so as to be suitable either for standard gauge or for the broad gauge, and extended from the Great Western main line at Bishop's Road (Paddington) to Victoria Street (which is now known as Farringdon Street). The line was opened for traffic on the 10 January 1863. The *Great Western Railway* only worked the traffic which was run on the broad gauge. After about six months, disputes arose between the two companies, and their agreements were terminated. The *Metropolitan Railway Company*, after a period of seven days, resumed operations on its own account, this being done with the aid of the

(1) The line from Grange Court to Hereford, 22 1/2 miles in length, which had been opened for traffic on the 1 June 1855, was then converted. Meanwhile, the section from Grange Court to Gloucester, including Gloucester Station, had already been laid with a third rail.

On the 19 August 1869, as a temporary measure, trains on this section were replaced by omnibuses, and the conversion took place in six days; two days later the service was resumed with the standard gauge.

In 1872, the section of the *South Wales Railway* and the Merthyr Tydvil section of the *Vale of Neath*, as well as the line from Grange Court to Cheltenham, which had been gradually provided with third rails and which were in all about 312 miles in length, were converted. (*Railway Gazette* of the 19 November 1920.)

(1) See note (1) on the following page.

Great Northern Railway. In 1869, the third rail was taken up and only the standard gauge retained.

SPAIN. — The Spanish railways were laid to a different gauge from that used in the remainder of Europe, in order to secure isolation. The gauge was 1 m. 736 (5′ 8 3/8″) from centre to centre of the rails, but was later standardised to 1 m. 676 (5′ 6″) between rails. This gauge has remained the standard up to the present time, but in the last few years there has been a movement in favour of converting the gauge to 1 m. 435 (4′ 8 1/2″).

One may ask under what circumstances is such a conversion to be justified. The capital invested at the present time in the whole of the Spanish broad gauge lines is considerable. The break of gauge takes place at the frontier, where passenger trains as well as goods trains make a lengthy stop, and the latter would, in any case, require remarshalling. The inconvenience arising from the break of gauge is not very great in the case of passenger traffic, since it only means that passen-

(1) We give below, for the readers' information, a table of lines of the *Great Western Railway*, which are constructed to the broad gauge and afterwards converted to the standard gauge.

Sections of the Great Western Railway laid to the gauge of 7′ (2 m. 13).

SECTIONS.	Length in kilometres	Converted in
Princes Risborough Aylesbury	11	1868
Oxford, Wolverhampton and branches	144	1869
Grange Court (near Gloucester) Hereford	35	1869
Reading Basingstoke	26	1869
Maidenhead Oxford	60	1870
West Drayton Uxbridge	4	1871
Whitland Carmarthen	22	1871
Swindon Milford and branches	384	1872
Vale of Neath, Merthyr and Cheltenham to Grange Court branches	96	1872
Radley Abingdon	3	1872
Didcot Oxford	17	1872
Bristol & South Wales Union Railway	19	1873
Thingley Junction Dorchester:		
Westbury Salisbury		
Bathampton Bradford Junction		
Bristol Frome	317	1874
Reading Holt Junction and branches		
Dorchester Weymouth-Southcote J. Reading	14	1874
Various branches	24	1875-1880
Durston Yeovil	33	1880
Barnstaple, Norton Fitzwarren, Minehead	108	1881-1882
Tiverton Junction, Tiverton	7	1884
Creech Junction Chard	19	1891
London Penzance	482	1892
Mutley Laucester	...	...

gers have to change from one train to another, and this is not very serious. As regards goods traffic, everything has to be transhipped.

The interchange traffic between France and Spain was, in 1921, about 320 000 t. If the gauge was standardised, there would be a saving equal to the cost of transhipping, but on the other hand there would be an additional expenditure equal to a proportional part of the interest on the capital necessary for the conversion of gauge over the whole of the broad gauge system. It would certainly seem, under these conditions, that at the present time a change of gauge is not justifiable.

On the other hand, the question of constructing a standard gauge line for fast trains from the French frontier to Madrid and Algeciras has been looked into, this line being particularly intended for passenger traffic. Here again it certainly seems that a broad gauge line would answer the same purpose and would give rise to less complication in the system as a whole than the introduction of the new gauge, which is different from that which already exists.

HOLLAND. — As is well known, the first Dutch lines were constructed at the instigation of the Crown. These were the lines of the *Rhenan Amsterdam Railway*, which runs through Utrecht to Arnhem on the German frontier, and was laid to the gauge of 2 m. (6′ 6 3/4″) between the centres of rails, or 1 m. 94 (6′ 4 3/8″) between the inner faces [1].

The *Amsterdam to Rotterdam Railway* [2], which runs via Haarlem and The Hague, and is 83 km. (52 miles) in length, was laid to the same gauge.

No inconvenience was experienced until the railway was linked up with the German system at Arnhem. This line was converted to standard gauge in 1856 and that from Amsterdam to Rotterdam from 1865 to 1867.

POLAND. — The Polish railway system was constructed by Russia to the gauge of 1 m. 52 (5′), the *Warsaw Vienna Railway* being the only one to standard gauge. During the war, the Germans, who were in occupation of the country, converted the whole system to standard gauge.

CHAPTER XVII. — *F*) GENERAL STANDARDISATION OF THE GAUGES IN ONE COUNTRY OR TERRITORY (*continued*).

2. — Africa.

SOUTH AFRICA. — In this case there have been three series of conversions at widely different times. Although all these may have been carried out in the interests of standardisation, this was not the immediate reason of it being done; we will therefore deal with these cases separately.

A) *Early gauge conversions.* — When railway construction was first commenced in South Africa, no attempt was made to determine the most suitable gauge, and the first lines were laid to the standard gauge, as used in Europe.

In Cape Colony, the first line was that from the Cape Town to Wellington with a branch to Wynberg, of which 63 miles (102 km.) were opened to traffic in 1863, and these were taken over by the State in 1872.

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(1) According to *The Locomotive Magazine*.

(2) Information kindly furnished by the Dutch Railways.

In Natal, the first line, which was only 2 miles (3 km.) in length, was opened in 1860 and was laid to the same gauge. This was the first railway to be opened for traffic in Africa. The line was lengthened somewhat and reached the River Umgeni, 4 miles (6.2 km.) away in 1874. This standard gauge line was taken over by the Natal Government in 1876.

In 1875, Cape Colony extended its existing lines, and this was done to the gauge of 3′ 6″ for reasons of economy.

Almost immediately the inconvenience of the break of gauge was felt, as the traffic was for the most part export traffic. For this reason a gradual conversion from the standard gauge to the narrow gauge was carried out [1].

[1] This is how it was done. In the first place, a narrow gauge *loop line* was constructed from Durban Road to Klapmuts, a station situated on the standard gauge line, and from this point to Wellington a third rail was laid so as to allow narrow gauge rolling stock to have access to the broad gauge terminus and to continue from there over the narrow gauge system. Subsequently the rail corresponding to the broad gauge between Wellington and Klapmuts was taken up, the latter therefore becoming the broad gauge rail head, a narrow gauge rail was laid between Cape Town and Durban Road, thus providing continuity of narrow gauge transport from the Cape to Klapmuts via Kraifontein.

Broad gauge rolling stock could also run from the Cape as far as Klapmuts, but via Stellenbosch.

In 1880, the gauge of the Stellenbosch branch was changed and a narrow gauge third rail was laid on the Wynberg line. In 1881 the broad gauge rail of this line was taken up. In this way the Cape Colony system was completely converted to narrow gauge.

In Natal, as the mileage to be relaid was small, a direct conversion was carried out.

The following table gives the lines converted :

Lines.	Miles.	Kilometres	Years.
Port Durban-Umgeni	6	10	1876
Cape Town-Wellington Salt River-Wynberg	64	103	1881

B) *Second stage of conversions.* — The railway gauge of South Africa having been fixed fixed at 3′ 6″, a certain number of adjoining railways were converted to this gauge, in some cases where they were incorporated into the system, and in other cases where there was a considerable amount of interchange traffic.

Beira Railway Company. — This railway, which is 328 km. (204 miles) in length, leads from the coast at Mutali to the Rhodesian Frontier. Constructed to the gauge of 2′ 1 1/2″, it was extended by the *Mashonaland Railway* as far as Salisbury, a further distance of 284 km. (177 miles), the latter line, in common with the remainder of the South African system being of the 3′ 6″ gauge. The *Beira Railway*, in the Portuguese territory of Mozambique, was also converted to this gauge.

German South West Africa. — After the occupation of this country by the South African troops, the principal lines, which were laid to the gauge of 2′ were converted to the 3′ 6″ gauge.

C) *Third stage of conversions.* — A certain number of railways had been constructed in South Africa to the gauge of 2′, for reasons of economy, but when these developed from being local branches and became main lines, it was necessary to undertake the conversion of some of these to the 3′ 6″ gauge.

Pankop Railway. — The conversion of this railway, which is 27 miles in length, and was laid to the gauge of 2′, to the 3′ 6″ gauge has been decided upon and will be shortly commenced.

Belgian Congo. — The first line to be constructed was that from Matadi to Leopoldville, with the object of providing continuous transport between the sea coast and the upper river. As funds were

lacking, it was built as cheaply as possible and was wisely laid to the gauge of 2′ 6″ (0 m. 765) [1].

Since then, three other railways have been constructed.

The *Mayumbe Railway*, a line for timber traffic, connecting the forests with a port on the river. Gauge is 0 m. 615 (2′).

The *Great Lakes Railway*, runs round the series of rapids on the upper river and connects them with Tanganyka. It was constructed to the 1 m. (3′ 3 3/8″) gauge.

The *Lower Congo and Katanga Railway* connects up with the British lines of South Africa and has to carry an important interchange traffic. It was therefore constructed to the same gauge of 1 m. 067 (3′ 6″).

All these railways are at the present time separate from each other, but this will not be so in the future.

The question of the general standardisation of gauge has not yet been considered by the Colonial authorities, but it should, however, be looked into. It does not appear likely that the standard gauge (4′ 8 1/2″) will be adopted, as a gauge of about 1 m. will be sufficient for a long time to come, and there are still many railways to be constructed. A choice must be made, however, between the gauges of 0 m. 765, 1 m. and 1 m. 067 (2′ 6″, 3′ 3 3/8″ and 3′ 6″). One can see already that the Lower Congo line, which is laid to the gauge of 0 m. 765, will not be sufficient for traffic requirements in the future, and this may therefore be eliminated as being suitable as a general gauge.

Conversions to the gauge of 1 m. or 1 m. 067 would cost about the same in either case. On the other hand, it is probable that the Southern half of Africa will only have lines of 1 m. 067 gauge, which is that of the *Lower Congo to Katanga Railway*, and which connects to a system of 21 888 km. (13 600 miles) of lines open for traffic.

It is therefore probable that it is the latter gauge which should be decided upon.

CHAPTER XVIII. — *F*) GENERAL STANDARDISATION OF THE GAUGES IN ONE COUNTRY OR TERRITORY (*continued*).

3. — America.

ARGENTINE. — In South America, the problem of the break of gauge does not yet present any very serious difficulty, but this will not be so in the future, especially in the case of the Argentine.

Taken as a whole, the Argentine railway system consists of a series of lines radiating from Buenos Ayres into the interior and constructed by large English companies to a broad gauge of 5′ 6″. This gauge was adopted for no particular reason, but it is well suited to the needs of the country, not because of the increased loading gauge used (since this is not fully utilised), but because stone is almost totally lacking in the enormous expanse of the planes, and therefore over these sections it is necessary to use only earth ballast in order to avoid the high cost of gravel or broken stone ballast. The broad gauge gives a greater stability to the rolling stock than the narrow gauge and allows higher speeds to be attained.

[1] See note on page 175/93 for information as regards the gauge and rolling stock.

The Argentine Government subsequently wished to provide the mountainous regions with railways constructed in a more economical manner, and for this reason adopted the 1 m. (3′ 3 3/8″) gauge, and a considerable amount of track was laid to this, which had reached 12 472 km. (7 750 miles) in length by the 1 January 1921. This was added to by other lines constructed by private companies : the *French Company of the Santa Fe Railway* and the *British Cordoba Company*, but what might have been forseen happened. In order to avoid loss through reloading in the case of traffic consigned to Buenos Ayres, these two Companies sought direct access to this place. The *General Railway Company of Buenos Ayres Province*, whose lines are laid to the 1 m. gauge, established connections between Santa Fe and other towns and the Capital, while the *Cordoba Company* built an extension as far as Buenos Ayres, and finally other lines of 1 m. gauge were constructed in the plains, namely, the *Midland Railway of Buenos Ayres* and the *Fifth Meridian Railway* which is situated in the Buenos Ayres district.

In this way there is at the present time a close net work of broad gauge lines in the plains, and an outlying metre gauge system which penetrates into the plains and also possesses lines radiating from Buenos Ayres and interwoven with the broad gauge system, and this is not all.

There is a large strip of territory which comprises the Provinces of Entre Rios and Corrientes. These are bounded by large rivers which separate them from the neighbouring states, which are Uruguay on the east, Paraguay on the north, and also from the other Argentine Provinces on the west. The direction of traffic is almost entirely towards Buenos Ayres, either by railway or by the bounding navigable rivers, and there is very little traffic towards the neighbouring states or provinces. Further, the lines of Uruguay being of the standard gauge of 1 m. 435 (4′ 8 1/2″), the two English companies which constructed the railways of the Entre Rios and Corrientes Provinces adopted the same gauge, and the Argentine Company, the *Central Buenos Ayres Railway*, also constructed a line, 101 km. (63 miles) in length, to the standard gauge, which gives direct access to Buenos Ayres. The passage of the Rio Parana in the south, and the Rio Parana in the north is made by means of « ferry boats ». The *Central Railway of Paraguay* which forms a prolongation of these lines to the north and which was constructed to the gauge of 1 m. 60 (5′ 3″) (1), was converted in 1913 to the 1 m. 435 (4′ 8 1/2″) gauge. In this way a complete system of 1 m. 435 gauge thus came into existence which extends from Paraguay to Buenos Ayres and passes through the two Provinces of Entre Rios and Corrientes. This is therefore a third element which must be taken into account in examining the situation in the Argentine.

Mr. Lavis made an interesting study of this question in 1913-1914. He concludes that the standard gauge for the Argentine ought to be the 4′ 8 1/2″. We do not agree with him for the following reasons :

If one wishes to get the same result from the 1 m. (3′ 3 3/8″) gauge as can be obtained with the standard gauge, we fully agree with Mr. Lavis. For similar speeds, the 1 m. gauge would have to be so well laid that it would be as expensive as the standard gauge, and would moreover not allow of speeds higher than 50 miles (80 km.) per hour under the

(1) This is the Brazilian broad gauge.

most favourable conditions. As regards the tonnage transported by comparable trains, the 1 m. gauge is certainly very inferior to the standard gauge, and under these conditions one could not agree that it would be adopted in preference to the latter, but this is not quite the case, and it appears that one should look into this particular problem and not be unduly influenced by the results obtained on the standard gauge in countries such as the United States and apply these results to the Argentine where economic conditions are quite different.

We are quite aware that almost the whole of the large amount of railway which was originally laid to the gauge of 3′ in the United States has been converted to 4′ 8 1/2″, but account must be taken of the large proportion of American lines which are in the receivers hands, and this naturally indicates that the construction or the methods of operation of many of these are much too costly for the country and the traffic which they have to handle. This is a disadvantage of pushing standardisation too far and of making it even apply to branch lines. To return to the question of the Argentine, our conclusions on the subject are as follows, if one compares the 1 m. gauge with the broader gauges of 4′ 8 1/2″ or 5′ 6″ :

a) In easy country, that is to say, in the plains, the difference in the cost of construction is not sufficient to justify the use of the 1 m. gauge;

b) In outlying districts in the plains which are not yet colonised, it is as a rule necessary to use a broad gauge (5′ 6″ or 4′ 8 1/2″) with a very light track with the intention of strengthening the line when the increased traffic makes it necessary;

c) In mountainous country where there is a heavy traffic, one should also use a broad gauge;

d) In outlying mountainous districts the traffic will not as a rule justify the cost of the broad gauge, and one should then use the 1 m. gauge;

e) The same applies to partially explored districts which require to be opened out. If this is done, at a later date and when the traffic makes it necessary, the gauge can be widened.

We have now to choose between the broader gauges of 5′ 6″ and 4′ 8 1/2″.

As regards capacity, the latter is sufficient for all requirements. When the line is laid in easy country, the difference between the price is insignificant. Moreover, we have mentioned above that the increase in stability which results from the wider gauge is useful, but this should not be the only factor in determining our choice.

The considerations which should guide us are as follows :

1° Communications with neighbouring countries;

2° Internal traffic of the Republic;

3° The mileage of either gauge already in existence.

1° Communications with neighbouring countries. — In South America the bulk of the traffic flows from the interior to the river side or sea coast ports; imports consist of products necessary for the development of the country and of opening up colonisation. Moreover, there is generally jealousy between neighbouring countries. The Argentine and Brazil are not on friendly terms. Chili, Bolivia and

Peru were in a state of war a short time ago.

Beyond import or export traffic, the traffic between neighbouring states is not important, except when one of these is cut off from the sea. Where one country is surrounded by other republics, it has to submit to the conditions which the latter impose upon it. This is the case of Bolivia and Paraguay which are dependent on their neighbours as regards communications and find their safety in the competition which exists between them in providing this traffic.

The railway exchange traffic between the Argentine and the neighbouring countries is confined to the traffic with Bolivia, Chili and Peru; as regards Brazil it is non-existant.

Bolivia has access to the sea on several sides, the shortest route, which reaches the Pacific either through Chili, or through Peru, entails the necessity of climbing the Andes. The route by Brazil and the river basin of the Amazon is an immense distance, while that through the Argentine is very long. In fact, from Quiaca, the frontier station, it is 1 907 km. (1 185 miles) to Buenos Ayres by the 1 m. gauge, and only 1 795 km. (1 115 miles) if one joins the broad gauge of the *Central Argentine Railway* at Tucuman. In May 1922 « limited » trains took 48 hours for the total journey, that is to say, an average speed of 37.4 km. (23.2 miles) per hour.

Communication between the Argentine and Chili is carried out by the *Transandine Argentine & Chilian Railways* with the gauge of 1 m., the sections in the Argentine and in Chili having a gauge of 5′ 6″. At the above date it took 30 hours to cover the 1 224 km. (761 miles) from Buenos Ayres to the frontier (las Cuevas), that is to say, an average speed of 40 km. (25 miles) per hour, and 39 hours for 1 440 km. (895 miles) from Buenos Ayres to Santiago, at an average speed of 37 km. (23 miles) per hour, inclusing crossing the Andes at an altitude of 3 190 m. (10 470′).

It is no easier to reach Bolivia from Buenos Ayres than it is to go to Chili, because it is necessary to climb the high plateaux, and the construction of the Andes railways is costly. It is therefore necessary to adopt a gauge which is suitable to the financial resources which are available. In any case it allows passengers to be carried in this case with a change of train, but this is not a very great inconvenience. Goods traffic has to go by a long and costly route through the Argentine, and only goods of certain value can pay for the cost of transhipment where this has to be carried out.

As regards Paraguay, the only access to the sea at the present time is through the Argentine, either by river or by rail. Through railway communication is now effected by a series of railways which are constructed to the standard gauge, and the Rio Paraguay and the Rio Parana are crossed by *train ferries*. This international line is made up as follows :

Buenos-Ayres to Zarate . . .	101 km. (62.7 miles) by the Central of Buenos-Ayres Railway.
Zarate to Ibicuy.	81 km. (50 miles) (train ferry over the Rio Parana).
Ibicuy to Concordia	362 km. (225 miles) by the Entrerios Railway.
Concordia to Posadas	598 km. (372 miles) by the North Eastern Railway.
Posadas to Cacu Cua	2 km. (1.24 miles) (train ferry over the Rio Paraguay).
Cacu Cua to Asuncion	370 km. (230 miles) by the Central of Paraguay Railway.

The 1 514 km. (940 miles) which separate the two Capitals are covered by through trains without a change of train in 54 1/2 hours, that is at an average speed of 27.8 km. (17.3 miles) per hour (in May 1922).

Broad gauge in neighbouring countries. — The majority of the Brazilian railways are to the gauge of 1 m. (3′ 3 3/8″). This is not the case in the Central States where there is a railway system of the gauge of 1 m. 60 (5′ 3″). It may be said that in the distant future it may be necessary to change the 1 m. gauge of the Southern States and adopt a larger gauge, probably the 1 m. 60 gauge.

The gauge of the Bolivian railways is also 1 m. This is reached by the broad gauge line from Buenos Ayres to Tucuman, 1 176 km. (730 miles) in length, and then by 619 km. (384 miles) of 1 m. gauge from Tucuman to the frontier.

In Chili, in the Central Provinces, a gauge of 1 m. 676 (5′ 6″) is used, as in the Argentine. The outlying lines are to the gauge of 1 m. with a few exceptions, which however are gradually disappearing.

To summarise, the present through traffic between the Argentine and Chili on the one hand, and the Argentine and Bolivia on the other, is carried by lines of 1 m. gauge, while communication between the Argentine and Paraguay is effected by means of a standard gauge line. Communication with Brazil is at present non-existant, but this country uses lines of 1 m. and 1 m. 60 (5′ 3″) gauges, while the standard gauge of 1 m. 435 (4′ 8 1/2″) is not used.

2° **Internal traffic.** — There is, and there probably will be for a long time, very little interchange traffic between the localities situated in the provinces served by the standard gauge systems and the territories situated in the east and in the west.

3° **Use at the present time of various gauges in the Argentine.** — We give below figures taken from the *Estadistica de los Ferrocarriles en explotacion,* the last edition published in 1920, but dealing with the year 1915. The present day do not differ sufficiently to have any influence either one way or the other.

On the 1st January 1916 there were open for traffic :

20 742 km. (12 888 miles) of broad gauge lines, that is 61.5 % of the total;

2 677 km. (1 664 miles) of standard gauge lines (4′ 8 1/2″), that is 8 % of the total;

10 291 km. (6 395 miles) of 1 m. gauge lines, that is 30.5 % of the total, including secondary lines.

We will give a brief review of the results which will arise from the adoption of one of the following gauges as a standard :

1° The 1 m. 435 (4′ 8 1/2″) gauge;
2° The 1 m. (3′ 3 3/8″) gauge;
3° The 1 m. 67 (5′ 6″) gauge.

First hypothesis. — The 1 m. 435 (4′ 8 1/2″) gauge. — If it were decided to adopt this gauge for the whole of the system, (which already gives access to Paraguay without transhipping) it would be necessary to convert the whole of the Argentine broad gauge system, as well as the 1 m. gauge, that is 92 % of the total system. As the standard gauge does not exist in Chili or in Brazil, the Argentine would be isolated from these countries unless the latter also adopted this gauge which they do not at the present use, and this would be very improbable.

Second hypothesis. — 1 m. (3′ 3 3/8″) gauge. — To convert all the lines to the gauge of 1 m. would be false economy and a great mistake, and this we need not discuss.

Third hypothesis. — Adoption by the Argentine of the broad gauge for the whole of the system. — There remains the adoption of the broad gauge for the whole of the system. Broadly speaking, it would be necessary to convert to this gauge 10 291 km. (6 395 miles) of 1 m. gauge and 2 677 km. (1 664 miles which are at present laid to the standard gauge, that is to say, 38.5 % of the total system.

On the other hand, 20 742 km. (12 888 miles) which are now laid to the broad gauge and which are the best equipped lines in the country would be unchanged. Moreover, it is admitted that it will at some time be necessary in any case to relay the 1 m. gauge lines, and there would be very little difference between the cost of converting these to standard gauge or to broad gauge.

The standard gauge system of Entre-Rios and Corrientes only comprises 8 % of the total Argentine system and will meet all the traffic requirements for a long time to come, because there is very little interchange traffic with other lines. One might therefore allow these to remain as standard gauge until the traffic justifies their conversion, and the gauge could then be increased, which would not be a very costly matter, because the loading gauge of the standard gauge lines and of the broad gauge are not very different and the country is generally speaking level.

We will now consider the question from an international point of view.

In Chili, this gauge already exists in the Central States, it is therefore likely that this is the gauge which would be adopted for the general system.

In Brazil, the gauge, which is 1 m. 60 (5′ 3″), only differs by 3″. When an agreement is reached between the two great Republics, the Central Brazilian lines could be converted to 1 m. 67 (5′ 6″) at very little cost.

Finally, in the whole of South America, by far the most important system is the Argentine broad gauge, since it consists of 21 476 km. (13 345 miles) out of a total of 37 516 km. (23 312 miles) in this country while all the other States of South America taken together have only 46 430 km. (28 850 miles), from which must be deducted 2 300 km. (1 430 miles) of broad gauge in Chili and 1 676 km. (1 041 miles) of broad gauge in Brazil, while the standard gauge lines are only found in three groups situated : one in Peru and Chili (2 703 km. or 1 680 miles), the second in Uruguay (2 296 km. or 1 427 miles) and the third (3 774 km. or 2 345 miles) in the Argentine Provinces of Entre-Rios and Corrientes, and also in Paraguay.

Our conclusions for all these reasons, which are opposite to those of Mr. Lavis, is to retain two gauges in the Argentine; that of 1 m. 676 (5′ 6″) for the main lines and the 1 m. (3′ 3 3/8″) gauge for the supplementary outlying system.

Results of operation.

We give in table 55 a comparison of a certain number of traffic statistics for each of the three gauges in use in the Argentine, which take into consideration all the elements by which they may be influenced. The figures are the averages of all the railways in the Republic, and the returns upon which they have been based are the most recent published by the Government, in 1920. However, the

various lines are not absolutely comparable. It must be borne in mind that the broad gauge railways and the standard gauge railways are situated almost entirely in flat country, while the 1 m. gauge is only employed in mountainous districts. These comparisons are therefore hardly fair to the latter; they show, however, that there is no great advantage in using the standard gauge of 1 m. 435 (4′ 8 1/2″).

TABLE 55.

Gauge		1 m.	1 m. 435	1 m. 676
Paying load per train-kilometre	Tonnes	*93*	*95*	121
Dead weight per train-kilometre	—	246	*307*	*369*
Total weight (including locomotive) per train-kilometre	—	338	402	490
Consumption of fuel per engine-kilometre	Kilogrammes	10.425	*12.584*	*12.566*
Average length of haul per tonne	Kilometres	23	171	221
Paying load	Per cent, of total weight, engine included.	*27*	*24*	*24*
Total weight per train-kilometre (excluding locomotive)	Tonnes	267	331	396
Fuel burnt per tonne-kilometre	Kilogrammes	0.054 (*a*)	0.046	0.039
Ratio of gradients to level portions of line.	Per cent	205 (*a*)	179	228

(*a*) The average gradients are much more severe for the 1 m. gauge than for the broader gauges.

BRAZIL. — The problem of the general standardisation of railways is not at the present an urgent one in Brazil, as the country is too large. Many of the States are in reality separate countries and relatively to the total extent of the country the railway system is still in its initial stages. A decision should, however, be come to as to the gauges to be employed, and these should be adhered to so that the situation shall not in the future become like that in the Argentine and in British India, where lines of different gauges are needlessly interwoven.

The more important lines in the centre of the country have been constructed to the broad gauge, while the others are of narrow gauge. The broad gauge adopted in the first place was that of the first railway constructed in Brazil, which was the *Maua Railway* in the neighbourhood of Rio, 16 km. (10 miles) in length, which was opened to traffic in 1854, the gauge being 5′ 6″ (1 m. 676) like that of the Argentine system. Subsequently a gauge of 5′ 3″ (1 m. 6) was adopted, a modification which it is difficult to explain unless it arose from the wish to have a different gauge from that of the neighbouring countries, and this is the gauge to which the lines of the *Don Pedro II Railway* (now the Brazil Railway) (figs. 20 and 21) and the *Paulista Company* and the *São Paulo Railway*, which are still in existence, were constructed.

The construction of other lines to the same gauge was begun, but it was soon found that this was scarcely necessary in large undeveloped districts, and with the exception of the broad gauge railways,

which we have mentioned above, the others were altered to the gauge of 1 m. (1).

The 1 m. gauge was for the most part adopted for the other railways. The gauge of some lines varied a little, but one after another they were altered to this gauge (2).

In addition to these there are 632 km. (393 miles) of 0 m. 60 (2′) gauge and 723 km. (449 miles) of 0 m. 76 (2′ 6″) gauge.

Fig. 20. — Railways of various gauges in the neighbourhood of Rio de Janeiro.

EXPLANATION :	———	5′ 3″ gauge.
	———	1 m. (3′ 3 3/8″) gauge.
	═══	Mixed gauge 1 m. 60 and 1 m. (5′ 3″ and 3′ 3 3/8″).

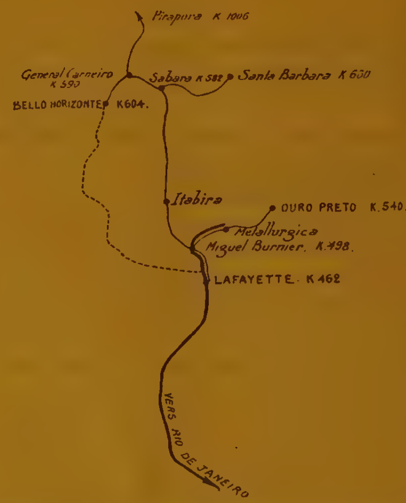

Fig. 21. — Northern portion of the Central Railway of Brazil (5′ 3″ and 1 m. [3′ 3 3/8″] gauge).

EXPLANATION :	———	5′ 3″ gauge.
	———	1 m. (3′ 3 3/8″) gauge.
	═══	Mixed gauge 1 m. 60 and 1 m. (5′ 3″ and 3′ 3 3/8″).
	------	1 m. 60 (5′ 3″) gauge under construction.

(1) *Brazilian railways on which the broad gauge has been reduced to the 1 m. gauge.*

RAILWAY.	Mileage.	Year of conversion.
Recife and São Francisco	125 km.	1905
Bahia and São Francisco	123 —	1911
Porto Novo branch	64 —	1911
Nichteroy to Cachoeiras	73 —	...
Rio Grande to Bage	...	(a)

(a) Gauge altered whilst under construction

(2) See note (*) on the following page.

As a general rule it appears that railway gauges in Brazil will be as follows :

Broad gauge for the main lines;

1 m. (3′ 3 3/8″) gauge for the majority of the system;

0 m. 60 (2′) gauge for light railways in districts which require a railway, but where it is not likely that heavy traffic will be encountered for a long time to come.

CANADA. — The problem of the general standardisation of gauge arose here, as in the United States, fifty years ago, but we may, however, mention a few facts. At that time there were, in addition to the standard gauge, a certain number of lines of broader gauge, the *Grand Trunk Railway* having a gauge of 5′ 6″.

The celebrated *Niagara Bridge* which united the Canadian *Great Western Railway*, with a gauge of 5′ 6″, to the American *Erie Railway*, which was laid to the gauge of 6′, connected two railways of different gauge. For this reason it was laid with three rails, and the third rail was continued over 87 miles of the Canadian line.

The *Prince Edward Island Railway*, 268 miles in length, which was laid to the gauge of 3′ 6″, is at the present time in course of conversion to the standard gauge.

Thus, in Canada at the present time there are only standard gauge lines. Many of these have been built to open up new districts which developed rapidly. In spite of this fact, these lines have been too costly for the country, and many of the more important Canadian railways have been insolvent. They have had to come to terms with the Government, who took them over in order to overcome their financial difficulties.

UNITED STATES. — As in the case of Europe, the early railways were laid to various gauges.

The *Quincy Railroad* in Massachusetts was opened in 1827 with a 5′ gauge, which was used for the heavy wagons employed for carrying stone [1].

This was followed by the *Maunch Chunk Road* in the coal mining district of Lehigh (Pennsylvania) laid to a gauge of 3′ 6″, which was that of the coal tubs used in the district [2].

The report on the projected construc-

(*) *Brazilian railways of which the gauge has been altered to the 1 m. gauge.*

RAILWAY.	Mileage.	Original gauge.	Year of conversion to 1 m. gauge.
Bahia Central	318 km.	1 m. 067	1912-1913
Uniao Valenciana	63 —	1 m. 100	1913
Cachoeira to Macuco	134 —	1 m. 110	...
Cordeira to Portella	78 —	1 m. 100	...
Old Ytuana	220 —	0 m. 960	1892-1894
Inbitiba to Campos	40 —	0 m. 950	...
Penha branch (Rio de Ouro)	61 —	0 m. 800	...
Barao de Araruama	... —	0 m. 650	1890
Vassourense system	6 —	0 m. 600	1912
Catazagues to San Antonio	48 —	0 m. 600	...
Funilense	41 —	0 m. 600	...

(1) 3 miles from the granite quarry to the port.

(2) 9 miles from the coal mines to the canal.

tion of the *Baltimore & Ohio Railroad* in 1828 recommended the adoption of the 4′ 8 1/2″ gauge, and Mr. Knight showed in 1830 that the best gauge was that of 4′ 9 1/4″. The 4′ 10″ gauge, which was also used, appears to have arisen from the desire to round off the former figure (1).

However, one continued to choose the gauge in accordance with local conditions, so that in 1873, in the State of Pennsylvania alone, there were nine different gauges for 105 railways, these ranging from 4′ 3″ to 6′. At this time the State of Ohio had 42 railways laid to seven different gauges (2).

The same variations were found throughout the whole country, with the exception of the State of New England, which from the beginning adopted the standard gauge of 4′ 8 1/2″ in order to avoid transhipping in its westward bound traffic (3).

Generally speaking, the standard gauge was used in the State of New England, the broad gauge in the South and in the other States various gauges (4).

There was no real effort towards standardisation until 1862, when President Lincoln passed a law which imposed a uniform gauge of 4′ 8 1/2″ over the whole of the *Union Pacific Railroad;* other railways in this district gradually had to fall into line, and in this way the *Erie Railroad*, which had been laid to the gauge of 6′ so as to keep to itself all the New York traffic, since no other railway was laid to this gauge, was obliged in 1882 to alter its gauge to 4′ 8 1/2″ at a cost of $25 000 000.

If in the first place broad gauge lines were constructed in order to obtain greater capacity, after some time it was necessary to extend these into districts which had not yet been opened up and for reasons of economy, one adopted a smaller gauge, which was generally 3′.

This gauge soon had a considerable body of opinion behind it, and thousands of miles were constructed. This satisfied the requirements of a number of lines, but was not satisfactory in other cases where it had been unwisely adopted and it was perhaps characteristic of the American mentality, that the whole system was condemned en masse, instead of the question being examined as to whether its use had been extended too far.

It was mainly after 1880 that a compaign was started in favour of the standardisation of gauges, and this was carried out for the most part in the course of the year 1886. In February of that year the principal railways of the South decided to standardise their gauge by the 31 May or the 1 June following at the latest. This remarkable conversion in so short a length of time, was effected by the date fixed, and 15 000 miles laid to various broad gauges were altered to the standard gauge (1).

The *American Railway Association* also adopted the 4′ 8 1/2″ gauge, and since then, nearly the whole of the railways of the country have been gradually converted.

On the other hand, the enlargement of

(1) See *Early History of Railways and Origin of Gauge*, by Steele (*American Society of Civil Engineers*, 5 July 1872).

(2) *American Railroad Manual* for 1873, by Vernon.

(3) *History of Transportation in the United States before 1860*, by Meyer.

(4) Much of this information has been kindly furnished by Mr. Johnson, *Bureau of Railway Economics*, Washington.

(1) See Hudson's Memoir to the *Western Society of Engineers* 7 June 1887, printed in the *Scientific American Supplement*, v. 24 of the 3 and 10 December 1887.

TABLE 56.

American railways in the receiver's hands from 1876 to 1921.

YEAR	Number of railways.	Mileage.	Liabilities, in dollars.
1876	42	6 662	467 000 000
1877	38	3 637	220 294 000
1878	27	2 320	92 385 000
1879	12	1 102	39 367 000
1880	13	885	140 265 000
1881	5	110	3 742 000
1882	12	912	39 074 000
1883	11	1 990	108 470 000
1884	37	11 038	714 755 000
1885	44	8 836	385 460 000
1886	13	1 799	70 346 000
1887	9	1 046	90 318 000
1888	23	3 270	186 814 000
1889	22	3 803	99 664 000
1890	26	2 963	105 007 000
1891	26	2 159	84 479 000
1892	36	10 508	357 692 000
1893	74	29 340	1 781 046 000
1894	38	7 025	395 791 000
1895	31	4 089	369 075 000
1896	34	5 441	275 597 000
1897	18	1 537	92 909 000
1898	18	2 069	138 701 000
1899	10	1 019	52 285 000
1900	16	1 165	72 234 000
1901	4	73	1 627 000
1902	5	278	5 835 000
1903	9	229	18 823 000
1904	8	744	36 089 000
1905	10	3 593	176 321 000
1906	6	204	55 042 000
1907	7	317	13 585 000
1908	24	8 009	596 369 000
1909	5	859	78 095 000
1910	7	735	51 427 500
1911	5	2 606	210 606 882
1912	13	3 784	182 112 497
1913	17	9 020	477 780 820
1914	22	4 222	199 571 446
1915	12	20 143	1 070 808 628
1916	9	4 439	208 159 689
1917	19	2 486	61 169 962
1918	8	3 519	242 090 800
1919	7	244	11 886 779
1920	10	541	21 620 150
1921	14	1 744	63 872 113

TABLE 57.

Railways sold by foreclosure, 1876 to 1921.

YEAR.	Number of railways.	Mileage.	Liabilities, in dollars.
1876	30	3 840	217 848 000
1877	54	3 875	198 984 000
1878	48	3 906	311 631 000
1879	65	4 909	245 288 000
1880	31	3 775	263 882 000
1881	29	2 617	137 923 000
1882	16	867	65 426 000
1883	18	1 354	47 100 000
1884	15	710	23 504 000
1885	22	3 156	278 394 000
1886	45	7 687	374 109 000
1887	31	5 478	328 181 000
1888	19	1 596	64 585 000
1889	25	2 930	137 815 000
1890	29	3 825	182 495 000
1891	21	3 223	169 069 000
1892	28	1 922	95 898 000
1893	25	1 613	79 924 000
1894	42	5 643	318 999 000
1895	52	12 831	761 791 000
1896	58	13 730	1 150 377 000
1897	42	6 675	517 680 000
1898	47	6 054	252 910 000
1899	32	4 294	267 534 000
1900	24	3 477	190 374 000
1901	17	1 139	85 808 000
1902	20	693	39 788 000
1903	13	555	15 885 000
1904	13	524	28 266 000
1905	6	679	20 307 000
1906	8	262	10 400 000
1907	6	114	13 777 000
1908	3	138	2 347 000
1909	12	2 629	250 033 000
1910	17	1 100	93 660 109
1911	13	1 386	40 741 543
1912	12	61	25 910 990
1913	6	1 159	86 163 850
1914	9	1 470	83 189 500
1915	11	3 914	285 258 782
1916	26	8 355	703 444 855
1917	20	10 963	557 846 348
1918	11	763	24 735 187
1919	8	459	15 479 587
1920	7	380	7 676 200
1921	11	4 173	306 123 942

TABLE 58.

Mileage of railways in the receiver's hands.

(Figures up to 1919 inclusive, taken from the *Interstate Commerce Commission Statistics* for the year ending 31 December 1919.)

Year ending		Miles of railway worked by the receivers at the end of the year.	Increase or decrease of miles of railway worked during the year.	Number of railways in the receiver's hands at the end of the year.
30 June	1894	40 819	...	192
	1895	37 856	— 2 963	169
	1896	30 476	— 7 380	151
	1897	18 862	— 11 614	128
	1898	12 745	— 6 117	94
	1899	9 853	— 2 892	71
	1900	4 178	— 5 675	52
	1901	2 497	— 1 681	45
	1902	1 475	— 1 022	27
	1903	1 185	— 290	27
	1904	1 325	+ 138	28
	1905	796	— 527	26
	1906	3 175	+ 3 175	34
	1907	3 926	— 45	29
	1908	9 529	+ 5 603	52
	1909	10 530	+ 1 001	44
	1910	5 257	— 5 273	39
	1911	4 593	— 664	39
	1912	9 786	+ 5 193	44
	1913	16 286	+ 6 500	49
	1914	18 608	+ 2 322	68
	1915	30 223	+ 11 615	85
	1916	37 353	+ 7 130	94
31 December	1916	34 804	— 2 550 (1)	80
	1917	17 376	— 17 426	82
	1918	19 208	+ 1 832	74
	1919	16 590	— 2 618	...
	1920	17 197	...	...
	1921	14 502	...	...

(1) A decrease for six months.

the narrow gauge lines to the standard gauge was undertaken on a large scale; these conversions taking place over about 5 000 miles of railway, of which about half (2 400 miles) belonged to the *Denver & Rio Grande Railway*. This line commenced by converting half of its system, and the remaining half was done in successive sections, the last of these being dealt with in 1912.

At the present time there are only three gauges in the United States for first class railways, namely, 4′ 8 1/2″, 4′ 9″ and 3′, and only 0.6 % of the total mileage is laid to these two latter gauges. The 4′ 9″ gauge has been retained on certain systems which have an important traffic of heavy goods.

It is obviously an advantage that all the railways of the country should be of the same gauge, but it is often necessary to build railways in districts in which the traffic for a long time will be too light to justify a standard gauge line. It is then necessary to build what the English call *light railways*, and what we call *chemins de fer économiques*, if this term is not generally used in too restricted a sense. This is not sufficiently recognized in the United States. When a railway is necessary, it is built to the standard gauge, though laid, it is true, with rails of light section and as a rule has too heavy rolling stock. It would be much cheaper to use lines of 3′ gauge, provided that a judicious choice is made of cases in which this gauge should be used. This is appreciated in fact, and in spite of the opposition which exists on principle, there are still in the United States 2 068 km. (1 290 miles) of first class lines of 3′ gauge.

Dr. Sandberg states that in Sweden there are railways costing 100 000 fr. per kilometre, and other railways costing 50 000 fr. per kilometre, and this is per-

haps a very good way of stating the point that we wish here to demonstrate.

The large number of American railways which are in the receiver's hands is obvious proof of the mistake committed in abandoning the narrow gauge as a matter of principle. It goes without saying that one cannot entirely blame the adoption of too large a gauge for the unsatisfactory state of affairs to which other causes have contributed, but it would appear that the question with which we are dealing must be included among these.

The mileage which is in the receiver's hands varies, as whenever possible these railways are sold.

Tables 56, 57 and 58 are interesting from this point of view. Tables 56 and 57 give for each year since 1876 to 1921 the mileage in the receiver's hands. Table 58 gives for each year since 1894 the total length of the system which they operate.

CHAPTER XIX. — *F*) GENERAL STANDARDISATION OF THE GAUGES IN ONE COUNTRY OR TERRITORY (*continued*).

4. — Asia.

British India. — Adoption of the 5′ 6″ gauge. — Railway construction in British India dates from 1845, and it was originally intended to use the standard gauge of 4′ 8 1/2″, but at that time there were in England a great number of supporters of the *Great Western Railway* broad gauge of 7′, and a mean gauge between the two extremes was adopted. The Consulting Engineer, Mr. Simms, proposed a gauge of 5′ 6″, which gives more space for the mechanism of the locomotive and « by lowering the centre of gravity, increased the stability » an important consideration in a country where cyclones are prevalent. This last argument led to it being agreed upon by the authorities, who adopted the 5′ 6″ gauge in spite of the advice of Lord Dalhousie, who was a supporter of the 6′ gauge.

Introduction of the 4′ gauge. — However, on account of the high cost the lines laid to the broad gauge and the insufficient return on the outlay, it became necessary to re-examine the question of the most suitable gauge, and it was then decided to adopt a cheaper gauge for secondary lines. For this reason, in 1865 the *Indian Branch Railway* was constructed with a gauge of 4′, but the traffic grew so rapidly that is was reconstructed to the broad gauge only a few years after it was opened.

Introduction of the 1 m. (3′ 3 3/8″) gauge. — In 1869, after a further examination of this question, it was decided again, for reasons of economy, to adopt a narrow gauge for the less important lines, and the 1 m. gauge was decided upon. This rapidly extended and penetrated into new districts which were becoming developed to such an extent that at the present time the narrow gauge system is almost as important as that of the broad gauge.

It has been said in criticism on this arrangement that the difference in cost between a well laid line of 1 m. gauge and a broad gauge light railway is very small. These, however, are lines of different categories, and it is useless to compare the one with the other. Had it not been for the economy realised by the substitution of the 1 m. gauge for the broad gauge, the Indian railway system

would never have developed so rapidly. However, the intermingling of lines of two gauges has its drawbacks, and therefore the question of the general standardisation of railways throughout British India is being examined. The advocates of standardisation have brought many arguments to prove the economy which would be realised, while their opponents have brought forward as many counter arguments.

We give below a few figures on this subject which may be of interest and which are taken from the official reports:

The cost of broad gauge lines in India, in 1905, was on the average £11 775 per mile. The cost of 1 m. gauge lines was £4 700 per mile, but it should be stated that the cost of construction of the broad gauge lines was increased by the presence of a number of bridges and tunnels of much greater length than were met with on the 1 m. line, the respective cost of these being 10 792 rupees and 2 149 rupees per mile of railway open. This argument cuts both ways, since it also proves that the 1 m. gauge lines situated in equally difficult country may be constructed without the necessity of an enormous quantity of works on account of the greater flexibility of the lines. Despite this, however, various authorities estimated at lower figures the difference in cost between the broad gauge and the 1 m. gauge in British India [1]. Their estimates are as follows:

TABLE 59.

—	Pounds sterling per mile.	Francs per kilometre.
Sir John Hackshaw	300	4 680
Sir John Fowler	633	9 900
Sir George Bruce	200	3 120
Sir Guilford Molesworth	425	6 800
Victoria	261	4 080
South Australia	350	5 460

We also give below, in table 60, the cost of conversion of the lines enlarged to the 5′ 6″ gauge, including the necessary rolling stock. These figures are taken from the Proceedings of the *Institution of Civil Engineers*, London, 1906.

TABLE 60.

RAILWAY.	Miles.	Kilometres.	Pounds sterling per mile.	Francs per kilometre (at par).
Salt branch (North Western Railway)	50	80	2 867	45 100 (*a*)
Nagpur Chattisgahr	145	233	2 583	40 600
Kotapura Firozur	28	45	1 472	23 200
Gudur Nellor	24	39	4 125	65 300

(*a*) Including the substitution of 75 lb. rails in place of 40 lb. rails.

(1) All this information was given in the course of a discussion at the *Institution of Civil Engineers*, London, vol. 164, 1906.

Introduction of the 0 m. 76 (2′ 6″) and 0 m. 60 (2′) gauges. — Since this time, light railways have been constructed and developed in mountainous districts, and a still narrower gauge has been used: 2′ 6″ or even 2′. One of the first of these was the *Darjeeling-Himalaya Railway* which carries an extremely important traffic, despite the narrowness of the gauge. This has developed to such an extent that at the present time there are in India 3 600 miles, (approximately 6 000 km.) of narrow gauge lines.

Conclusion. — The problem has thus become complicated by the introduction of this new gauge, and the 1 m. gauge has become an intermediate gauge. It is probable that a better arrangement may be arrived at as regards the use of these various gauges which have sometimes been unadvisably used and have therefore complicated the whole question (1).

Palestine. — Before the war there were in Palestine railways of 1 m. gauge, and others, notably the *Damascus* and *Hedjaz* lines which were of 1 m. 05 (3′ 5 3/8″) gauge. On account of the war, two gauges were decided upon successively for all the railways in the country, and successive conversions were carried out within a very short period.

The Turkish Government adopted a gauge of 1 m. 05 for the whole of the system, and converted to this gauge the 53 miles of line from *Jaffa* to *Jerusalem*, which was originally of 1 m. gauge.

During the British occupation, the standard gauge, which was that of the *Egyptian State Railways* at the military base, was adopted. The *Jaffa-Jerusalem Railway* was therefore reconverted to the 4′ 8 1/2″ gauge.

The 4′ 8 1/2″ gauge was also substituted in place of the 1 m. 05 gauge on the *Beersheba-Wadi-Surar Railway* (*Vale of Sorek*), 54 miles in length, which has since been dismantled.

CHAPTER XX. — *F*) GENERAL STANDARDISATION OF THE GAUGES IN ONE COUNTRY OR TERRITORY (*continued*).

5. — **Oceania.**

Australia. — Original adoption of the 5′ 3″ gauge. — There is nowhere perhaps where the gauge problem presents itself in such an acute form as in Australia. The Dominion is composed of six States of which nearly all unfortunately have a different gauge.

The great inconvenience which was experienced by the Mother country as a result of various gauges has urged British and Australian engineers to adopt a uniform gauge throughout the Australian continent.

In 1850 the chief engineer of the *Sydney Railroad & Tramway Company* (of New South Wales) recommended the Irish gauge of 5′ 3″, and the Act of 1852 rendered the use of this compulsory.

(1) Mr. Dawson (quoted above) thinks that the 1 m. gauge will finally give way to the broad gauge, because in India :

a) the capital invested in broad gauge lines is more than double that of the 1 m. gauge;

b) the broad gauge lines carried (in 1921) 80 % of the total tonnage;

c) the broad gauge is less costly from an operating point of view and much higher speeds are obtainable.

He maintains that narrow gauge light railways are necessary, and thinks that these should be of 2′ 6″ or 2′ gauge, but these would not replace the other gauges because of their limited capacity.

The colonies of *New South Wales*, *Victoria*, *South Australia*, *Tasmania* and *New Zealand*, who themselves were at that time considering railway construction, also agreed to its adoption.

INTRODUCTION OF 4′ 8 1/2″ GAUGE. — Meanwhile, the *Sydney Railroad & Tramway Company*, having changed its engineer, also changed its decision and decided upon the 4′ 8 1/2″ gauge. The other States had meanwhile ordered rolling stock; moreover, they thought this action somewhat high handed and would not reverse their previous decision. When in 1857 the Government of New South Wales took over the *Sydney Railroad & Tramway Company's* lines, they considered that it was too late to again reopen the question of gauge.

The gauge of the railways in *Tasmania* and *New Zealand* are independent of the others, since these islands have no railway communication with the other colonies, and we will therefore make no further mention of them here.

INTRODUCTION OF THE 3′ 6″ GAUGE. — After some time, the sparsely populated colony of Queensland considered that to develop their inland district it was necessary to connect these with the sea coast by railways constructed as cheaply as possible, and for this adopted the 3′ 6″ gauge, *Western Australia* did the same, since it had a preference for this gauge, and both *New Zealand* and *Tasmania* in which the first lines had been constructed to the broad gauge built extensions to the 3′ 6″ gauge and converted the lines already open to traffic. *South Australia* followed this example, without however converting the broad gauge lines of which it had considerable mileage at this period, but extensions were constructed to the gauge of 3′ 6″. The *Colony of Victoria* was the only one which remained faithful to the decision arrived at in the first place in spite of the campaign which took place about 1870, as also in *New South Wales*, in favour of the 3′ 6″ gauge.

In *Victoria* tenders were even called for for two lines, one of which was to be of 5′ 3″ and the other of 3′ 6″ gauge, but the comparative cost of the two gauges being only as £181 is to £150, no further action was taken.

FEDERAL LINES. — Many schemes were put forward for the standardisation of gauge, either by the conversion of one or of the other of the existing gauges, either totally or partially, or by the adoption of a third rail, especially when the Federal Government undertook the construction of transcontinental railways to connect the various States.

Although existing sections of the *North Federal line* were of 3′ 6″ gauge, it was not considered that this would be suitable for the whole of the system. The Federal Government therefore constructed and opened for traffic, in 1917, the whole of its transcontinental line from Port-Augusta to Kalgoorlie to the gauge of 4′ 8 1/2″, which was that of *New South Wales*, and also increased the mileage of broad gauge lines which were as follows on the 30 June 1920 :

TABLE 61.

Gauge.	Miles (kilometres)	State :
1 m. 435	6 113 (9 837)	New South Wales : Federal lines (Western Australia and Southern Australia).
1 m. 600	5 275 (8 489)	Southern Australia : Victoria.

NEED FOR STANDADISATION. — The mileage of each gauge open for traffic at the present time is as follows :

TABLE 62.

Length in miles and in kilometres.	5′ 3″	1 m. 435	3′ 6″	2′ 6″	2′
Miles	5 275	6 113	11 602	129	215
Kilometres	8 489	9 837	18 671	207	346

The question of the standardisation of gauge has been considered on several occasions.

In 1913 it was estimated that the cost of converting all the Australian continental railways would be £37 164 000 (equal at that time to 936 1/2 million francs).

The Conference of the Federal authorities, held in June 1920, considered the conversion of the lines adjoining the capitals of the States and supplementing these by the construction of certain new lines of 4′ 8 1/2″ gauge at an estimated cost of £26 581 000, of which £8 154 000 were for the new lines.

In July 1920 it was decided to appoint a Commission of international experts to look into the question, and this was nominated in February 1921. It advocated the 4′ 8 1/2″ gauge. At this time, the Conference of the various State railways estimated the total cost of conversion at £57 200 000 (that is 1 441 million francs at the pre-war rate of exchange). In view of the magnitude of this sum, it was only intended in the first place to standardise the trunk lines at a cost of 18 or 19 million pounds (453 to 491 million francs at the pre-war rate of exchange).

The question of rail gauge is complicated in Australia by the question of the loading gauge, as the Federal loading gauge for the 4′ 8 1/2″ line is larger than that for the 5′ 3″ gauge. Tables 63 and 64 give for each State the maximum dimensions of rolling stock at present used on the various systems.

NEW ZEALAND. — The situation in New Zealand is similar to that in South Africa, as in the first place railways were constructed to the broad gauge, but this was not continued.

Before 1871, as a matter of fact, railway concessions were held exclusively by the provincial authorities.

In 1863, the *Lyttleton-Canterbury Railway*, in the Province of that name (Southern Island), was laid to the Irish gauge of 5′ 3″, in accordance with the agreement come to between the British Colonies of Australia and of New Zealand, and this was laid with 75 lb. rails.

The *Auckland-Wakatou Railway* (Auckland Province) with a standard gauge of 4′ 8 1/2″ was opened for traffic in September 1873.

Finally, the *Province of Otago Railway* from Dunedin to Port Chalmers, with a gauge of 3′ 6″ was opened in the same year. It was worked by *Fairlie* locomotives.

When it was decided to standardise the gauges, the 3′ 6″ gauge was adopted because of the mountainous nature of the country and the economy in construction which could be realised thereby. The rolling stock of the 5′ 3″ lines were converted, with the exception of the locomotives which were sent to Australia.

Table 63.

Dimensions of passenger rolling stock.

Gauge.	State.	Height.		Width.		Length.		Tare.
1 m. 600	Victoria	10'	3 m 05	14' 2"	4 m. 32	74' 1" 1/4	22 m. 59	47-10
	South Australia . .	10' 4" 1/4	3 m. 16	14' 1" 3/4	4 m. 31	74' 1" 1/4	22 m. 59	40-11
1 m. 435	New South Wales . .	10' 6"	3 m. 20	14'	4 m. 27	74' 4" 1/2	22 m. 67	44-2
	Transaustralia . . .	10' 6"	3 m. 20	14' 6"	4 m. 42	78' 11" 1/2	24 m. 06	48
1 m. 067	Queensland	9' 4"	2 m. 84	12' 9"	3 m. 89	55' 5"	16 m. 89	26-17
	South Australia . .	9' 4" 3/8	2 m. 85	12' 1"	3 m. 69	62' 6"	19 m. 05	24-18
	Western Australia . .	8' 10"	2 m. 69	12' 7"	3 m. 84	62' 9"	19 m. 13	31-10
	Tasmania	9' 6"	2 m. 89	12' 5"	3 m. 79	64'	19 m. 51	30
	Northern Territory .	9' 4"	2 m. 84	12' 9"	3 m. 89	39'	11 m. 89	12
	Oodnadatta	10' 2"	3 m. 10	12' 4"	3 m. 76	39'	11 m. 89	12
0 m. 760	Victoria	7' 0" 1/4	2 m. 14	10' 4" 1/4	3 m. 16	31' 8"	9 m. 65	8-11
0 m. 610	Queensland	6' 3" 7/8	1 m. 93	10'	3 m. 05	22'	6 m. 71	3
	Tasmania	6' 6"	1 m. 98	10'	3 m. 05	30' 2"	9 m. 19	5-10

Table 64.

Maximum dimensions for freight stock.

Gauge.	State.	Height.		Width.		Length.		Tare.	Loading.
1 m. 600	Victoria	9' 7" 1/2	2 m. 93	13' 7" 3/4	4 m. 16	55' 4" 1/2	16 m. 87	20-13	30
	South Australia . .	10' 0" 1/4	3 m. 05	12' 10" 3/4	3 m. 93	43' 6"	13 m. 26	16	30
1 m. 435	New South Wales . .	9' 8"	2 m. 94	13' 6"	4 m. 11	60' 11"	18 m. 57	20-10	40
	Transaustralia . . .	10' 6"	3 m. 20	14' 6"	4 m. 42	47' 6" 1/2	14 m. 50	15	40
1 m. 067	Queensland	8' 9"	2 m. 67	12'	3 m. 66	45' 5"	13 m. 85	14-16	21
	South Australia . .	8' 6"	2 m. 59	12' 1"	3 m. 69	38' 9"	11 m. 81	11-15	25
	Western Australia . .	8' 8"	2 m. 64	12' 6"	3 m. 81	44' 9"	13 m. 64	17-18	27
	Tasmania	8' 6"	2 m. 59	11'	3 m. 35	40' 10"	12 m. 44	12-05	30
	Northern Territory .	9' 4"	2 m. 84	12' 9"	3 m. 89	34' 6"	10 m. 51	9-11	12
	Oodnadatta	10' 2"	3 m. 10	12' 4"	3 m. 76	18'	5 m. 49	5	5
0 m. 760	Victoria	6' 5" 1/2	1 m. 97	9' 7" 1/4	2 m. 92	27' 3" 3/4	8 m. 33	7-12	10
0 m. 610	Queensland	6' 6"	1 m. 98	9'	2 m. 74	22'	6 m. 71	4-10	16
	Tasmania	6'	1 m. 83	6' 6"	1 m. 98	27'	8 m. 23	5-15	20

It is not likely that the gauge which has been adopted will be again changed, as a number of works (especially the tunnel of Arthur's Pass which is more than 5 miles in length) render the conversion to a larger gauge far too difficult.

CHAPTER XXI. — GENERAL CONCLUSIONS.

We have endeavoured to show in the foregoing the influence of gauge on the construction and operation of railways, and to draw practical conclusions therefrom. For this reason we have dealt very thoroughly with the question of the break of gauge and with the question of conversion and standardisation.

All these problems are of the greatest importance and should be examined in each particular case, because their solution depends on a number of elements, all of which are variable (1). It will be sufficient, in order to demonstrate the importance of gauges other than the 4′ 8 1/2″, to draw attention to their considerable use, which amounts to one third of the total railway mileage. With this object we have drawn up, as completely as we have been able, the table of railways at present open for traffic, grouping the lines according to their gauge. These are made up as follows :

12 % are broad gauge railways (5′ 6″, 5′ 3″ or 5′);

67 % are standard gauge (4′ 8 1/2″);

21 % are narrow gauge, usually 3′ 6″, 1 m., 3′, 2′ 5 1/2″, 2′ 6″ or 2′.

We may perhaps best conclude this article by giving in detail the railway tabulated according to continent and gauge (table 65).

TABLE 65.

Table of railway mileage open for traffic tabulated according to gauge.

	I. Europe.	II. Africa.	III. America.	IV. Asia.	V. Oceania.	TOTAL.	Per cent.
1 m. 676	14 137	...	22 457	30 284	...		
1 m. 600	4 258	...	1 616	...	8 489	129 855	11 89
1 m. 52	38 648	...	80	9 886	...		
1 m. 435	231 582	5 702	477 967	16 230	9 982	741 463	66.73
1 m. 372	18	...	...	...	...		
1 m. 36	...	...	5	...	...		
1 m. 33	...	...	9	...	...		
1 m. 27	...	...	157	...	...	350	0.032
1 m. 219	23	...	...	...	...		
1 m. 20	44	...	...	...	...		
1 m. 10	35	...	...	...	...		
1 m. 093	59	...	...	...	...		

(1) We have resumed the discussion *The capacity and capabilities of various railway gauges*; it appears in the *Bulletin* of the *Belgian Society of Engineers and Manufacturers* 1923-1924.

We have completed this by an article dealing with *Railway gauges in all countries*, which appears in the *Bulletin* of the *Federation of Belgian Engineers*.

Table 65 (*continued*).

	I. Europe.	II. Africa.	III. America.	IV. Asia.	V. Oceania.	Total.	Per cent.
1 m. 067	3 057	28 282	4 003	18 340	24 723	78 405	7.06
1 m. 05	...	1 703	...	1 986	...	3 689	0.34
1 m.	26 061	11 992	44 518	31 521	29	114 121	10.28
0 m. 95	2 568	462	...	...	...	3 030	0.21
0 m. 91	3 991	...	8 148	...	183	12 322	1.11
0 m. 85	25	...	...	...	...	587	0.06
0 m. 82	61	...	...	...	...		
0 m. 80	234	...	...	...	...		
0 m. 78	267	...	...	...	...		
0 m. 76	4 858	1 399	2 301	5 241	207	18 950	1.71
0 m. 75	2 666	1 377	397	504	...		
0 m. 724	15	...	...	...	...	77	0.007
0 m. 70	24	...	...	...	...		
0 m. 686	29	...	...	...	...		
0 m. 66	...	...	9	...	...		
0 m. 60	1 227	3 056	2 368	1 347	401	8 399	0.77
0 m. 381	11	...	...	...	...	11	0.001
...	333 898	53 973	564 035	115 339	44 014	1 111 259	100

[686. 284 (.52)]

On the earthquake damage to the Japanese Government Railways,

By Mitsuo NAWA,
ENGINEER, GOVERNMENT RAILWAYS OF JAPAN.

Figs. 1 to 14, pp. 208 to 217.

INTRODUCTION.

The centre of the great earthquake of 1 September 1923, which visited, among other districts, the cities of Tokyo and Yokohama and caused widespread destruction in these localities, was apparently in the sea, some 50 miles south-southeast of Tokyo.

The seismometers in the seismological section of the Tokyo Imperial University ceased to record immediately after the first severe shock, and this made it difficult to obtain exact knowledge about the extent of vibration, but the maximum left on record shows 101 mm. (3.976 inches), in double amplitude and 1.5 seconds in period. Further, judging from the damage to various structures, the acceleration of vibration was about 900 mm. (35.434 inches) per second per second in the uptown districts, consisting of comparatively firm diluvial formation, and 1 500 to 2 000 mm. (60 to 80 inches) per second per second in the downtown districts consisting of soft alluvial formation or of reclaimed land. In Yokohama, Kamakura, Odawara, etc., which were near the seismic centre, it apparently reached more than 3 000 mm. (118 inches) per second per second.

So far as Tokyo is concerned, this recent earthquake shock seems to have been somewhat weaker than that which was experienced here 11 November 1855. Soon after the shock, fire broke out at more than eighty different spots in the city. The water-system was then discovered to have been damaged and to be for the time being useless. Moreover, strong tornadoes arose in rapid succession and greatly added to the force of the fire, and the variable nature of the wind, together with the tornadoes, made the fire spread in all directions. These circumstances made the damage far greater than that of 1855.

On 1 September, a low pressure passed over Tokyo and a storm raged in the morning, but it gradually subsided, and by the time of the first shock, it had become very fine with a cloudless sky and a gentle wind. From about one o'clock in the afternoon, whirlwinds raged one after another over the districts along the rivers Sumida and Kanda, and a cumulus which had appeared over the ward of Honjo and its neighbourhood at about five o'clock, remained till night, and, when the fire broke out, this cloud-bank, reflecting the flames, presented a magnificent but awe-inspiring spectacle.

Inasmuch as the railway is a long and slender structure, not confined to a small section, the fire damage to our State Railways was limited to a comparatively

Fig. 1. — Rough sketch of Government Railway lines in damaged districts.

small portion. The damage sustained was, for the most part, due to the earthquake, not to fire. The following is a summary of these damages :

Table showing the extent of the damage to the State Railways.

Districts damaged	About 3 270 square miles.
Lines damaged	372 miles.
Number of bridges damaged. .	68
Total length of damaged parts of bridges	15 285 feet.
Number of tunnels damaged. .	32
Total length of damaged parts of tunnels	2 855 feet.
Number of main buildings of stations damaged :	
Burnt brick work.	4
— wooden.	13
Collapsed or half collapsed wooden. . . .	22
Number of train accidents due to the earthquake	22
Number of locomotives burnt or damaged. . .	53
— of passenger cars burnt.	386
— of freight cars burnt	817
— of electric cars burnt.	31

I. — Bridges and arch bridges.

Damage to bridges comprised, for the most part, leaning, break, dislocation, overturning, etc., of abutments and piers. Iron girders sustained slight damage, except those which fell.

The bridge over the River Banyu on the Tokaido main line.

It consisted of two single track bridges, each with 28 spans of plate girders

70 feet long. The piers were made of bricks and hewn stones piled on elliptical wells of a 12 feet major axis and a 7 ft. 6 in. minor axis. Of these piers, 44 were broken at the point near the water line, and fell into the down stream, and the wells leaned and some of the centres shifted sidewise or along the track line by 2 to 3.5 feet.

As shown in the photograph, 47 girders were all thrown of the bridge into the river, thus impeding its flow.

The bridge over the River Sakawa on the Atami line.

It consisted of 8 spans of double track truss girders 150 feet long and two lines of 16 spans of single track plate girders 60 feet long. The piers for the 150 foot girders sustained no damage. These girders had reinforced concrete cylindrical wells 14 ft. 6 in. in diameter, 30 feet apart from centre to centre, and the curbs of the wells were about 50 feet deep in the ground. The wells were filled with concrete, on which concrete columns faced with masonry were built up to the bridgeseat and they were not connected with each other. Owing to the vibration, a span of truss girder 150 feet long shifted down the river, came off the bridgeseat and fell on its side upstream.

In previous earthquake, piers, which were built by connecting the two wells with an arch and making them one body in the upper part, had often been broken or cracked at the point where the arch connected the two wells. In the present instance, such damage occurred to several bridges. The bridge over the River Rokugo on the Tokaido main line consisted of two lines of 5 spans of double track truss girders 120 feet long and four lines of 24 spans of single track plate girders 44 feet long. On this bridge were laid two double tracks for steam and electric traction. At the centre, an elliptical well of 21 ft. 6 in. major axis and 14 ft. 6 in. minor axis was sunk and, on each side, a cylindrical well of 14 ft. 6 in. diameter, on which piers, as in the case of the bridge over the Sakawa, separately erected. Of these piers, only a single column was broken and no other damage was sustained. But as to the 120 foot span bridge on the Kei-hin (Tokyo-Yokohama) Electric Railway Co. line, which is near that particular bridge, but slightly down stream, all the five piers were cracked at a point under the arch, as might have been expected, for the piers had been constructed by connecting two wells and making them one body.

Arch bridge.

There was no arch bridge of long span in the districts sustaining heavy damage, but in those of short span, whether of brick or concrete, the side walls were forced out by the lateral pressure, the arch ring cracked lengthwise, and the bridge was broken and dislocated, thus sustaining serious damage.

II. — **Embankment and reclaimed land**.

Inasmuch as embankments and reclaimed land offer a very low resistance to shock, some of them which met the vibration at right angles were cracked longitudinally or wholly broken, their shape being completely destroyed. Moreover, the earth and gravel on the back of abutments considerably subsided and pushed forward the abutments or made them lean, so that at several points, the track, being suspended on the abutments and hanging in mid-air, presented a singular spectacle.

The subsidence of the reclaimed land at the stations of Shimosoga and Odawara, and at the wharves of Yokohama,

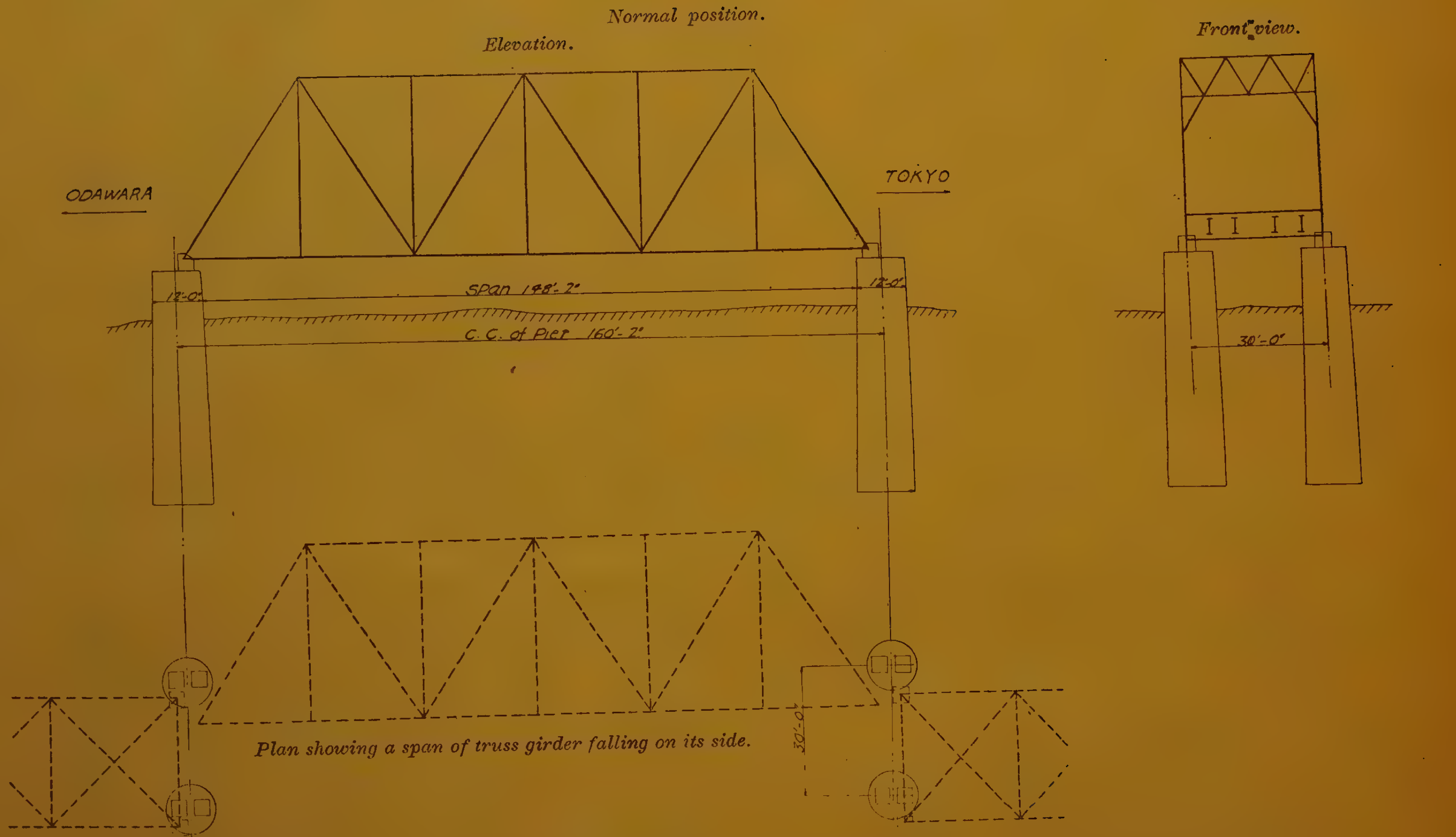

Fig. 2. — Sketch bridge over the River Sakawa.

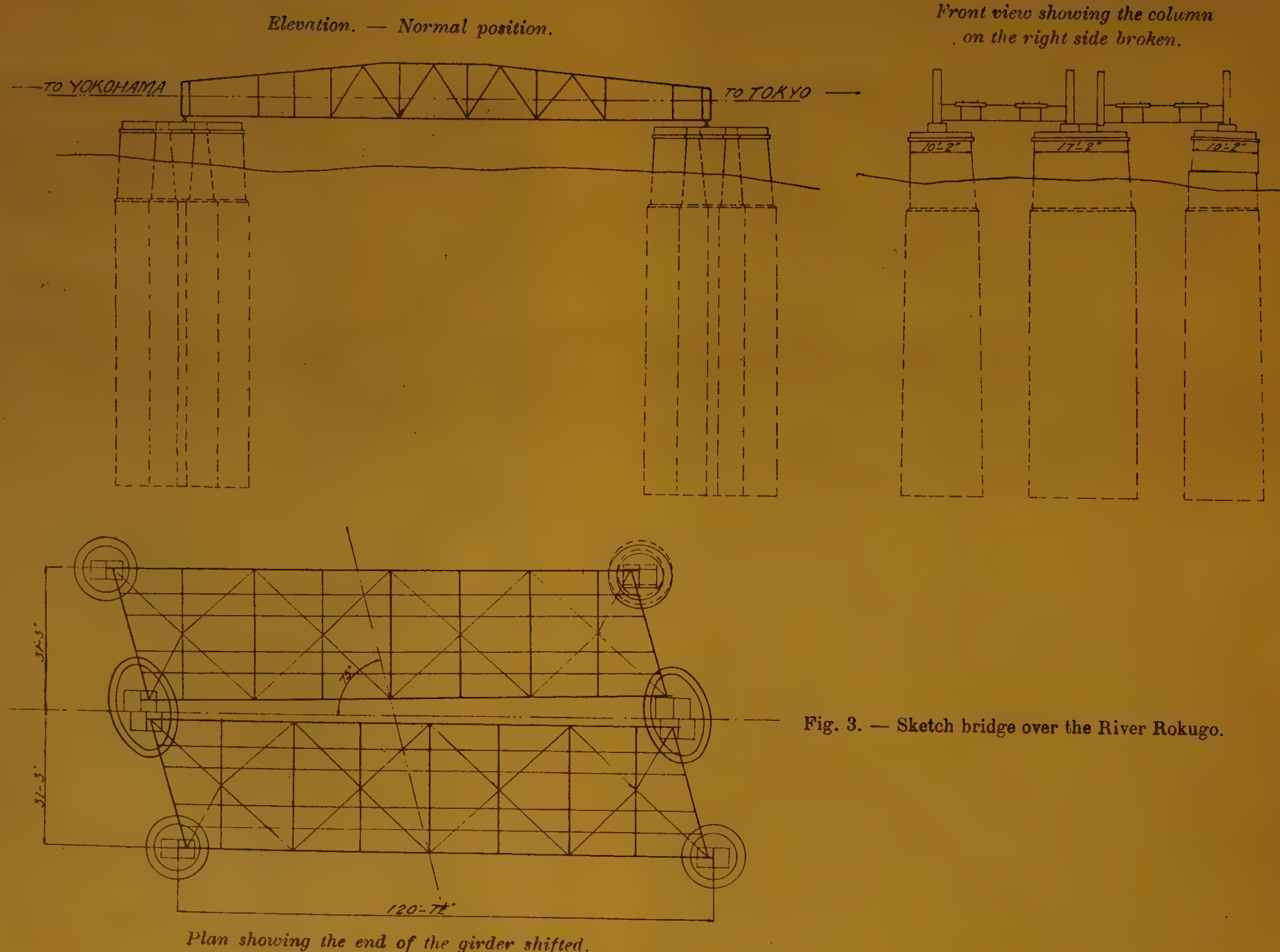

Fig. 3. — Sketch bridge over the River Rokugo.

Fig. 4. — The bridge over the River Rokugo on the Tokaido main line. A pier for the truss girder of 120 foot span broken.

Fig. 7. — An arch culvert near Matsuda Station on the Tokaido main line.

Fig. 5. — A warehouse at a wharf of Yokohama collapsed.

Fig. 6. — Only a shadow remains of the bridge over the River Banyu on the Tokaido main line.

8. — The bridge over the River Sakawa on the Atami line. A span of double track truss girder, 150 feet long, overthrown.

was most remarkable. There the track bent vertically or sidewise, and the building leaned or collapsed, producing an alarming sight. In Yokohama harbour most of the breakwaters and quay-walls also subsided, or were toppled over and sank completely beneath the water.

III. — Landslips and mudflows.

In the districts, where severe tremors occurred, as in the mountainous part of Hakone, steep mountain-sides, composed of rock or earth and sand, cracked at several points, with or without resultant landslips. The cracks in turn led to the permeation of rain water and caused landslips or mudflows, which burried or washed away houses, railways, forests and fields, and otherwise inflicted serious damage. The Hakone mountain ranges which were covered with green before the earthquake, now present many red patches, and what remains constitutes but a shadow of the former attractive view.

The landslips that brought about the greatest disaster occurred just above Nebukawa Station on the Atami line. It carried away the main building of the Station, together with a passenger train then stopping there, plunging them into the sea and killing more than one hundred persons, including passengers and train or station staff.

The greatest mudflow occurred also near Nebukawa Station, coming down along the upper stream of the River Shiraito and washing away the greater part of a bridge, together with its piers. This bridge was 105 feet high and consisted of 3 spans of truss girders 140 feet long and of 4 spans of plate girders 40 feet long.

IV. — Tunnels.

The damage to tunnels consisted, for the most part, of cracks made across the wall near the portal, these being due to earth and gravel above the portal sliding down and pushing out its upper parapet wall.

The interior of some tunnels was also damaged. The damage occurred where there was a fault, or softer soil and less surcharge, and may be said to be a special case.

V. — The elevated railway.

The elevated line of the Government Railways running through the city of Tokyo is laid in the downtown district consisting of soft ground. The greater part of the track has been built on arches of brick or reinforced concrete of 26 to 40 foot spans, the foundation of which were made by driving in pine wood piles and reinforced concrete piles, 48 feet in length. Where the ground is weaker, reinforced concrete slabs of 19 foot-span were inserted instead of arches. Further, steel plate girders were used over roadways, and Melan's reinforced concrete skew arches of 125 foot-span were built over the Sotobori Canal. This elevated line sustained almost no damage from the earthquake itself, some plate girders alone being shifted. But, as various articles were stored beneath the arches and slabs, these took fire and the inner bricks of the arches were affected by the intense heat and losing their coherence, flaked off in thin layers. Fire damage to the slabs seems to have been very slight.

The elevated line at Yokohama was laid upon an embankment. In a certain section, a vertical concrete retaining wall was used on each side, and in other section a similar wall was used on the one side and sodding with a 1 : 1 1/2 slope on the other. The intermediate fillings sank a few feet and the retaining wall, which had been vertically built, either

Fig. 9. — The bridge over the River Shiraito on the Atami line. Owing to a mudflow, two spans of double track truss girders 150 feet long and three spans of single track plate girders 40 feet long went out of shape, and no trace remains of the piers and abutments of these girders.

Fig. 10. — A cut gave way between Ochanomizu and Suidobashi Stations on the Chuo line, earth damming up the Kandagawa Canal.

Fig. 11. — Seto bridge No. 1 damaged on the Hojo line.

Fig. 12. — The temporary bridge over the Banyu on the Tokaido main line.

Fig. 13. — Brick arches of the elevated line sustaining no damage even from the greatest earthquake.

Fig. 14. — A reinforced concrete arch of the elevated line damaged by fire.
The reinforcement exposed inside the arch.

was forced out vertically or leaned slightly forward and laterally by 3 to 5 feet, and some poles for the electric contact line bent, as shown in the photograph. Owing, however, to the fact that expansion joints were applied vertically on the retaining wall 33 feet apart, no damage was suffered at any particular points.

VI. — **Buildings**.

The main building of Tokyo Station, which is a three-storied structure having a steel frame with brick wall, sustained no damage, in spite of its very large dimensions. The main buildings of Manseibasbi, Shimbashi and Yokohama Stations were two-storied brick structures and were gutted by fire, but their remaining walls show no trace of earthquake damage. The fan-shaped reinforced concrete engine houses at Shinagawa and Yokohama were built upon reclaimed land and have been cracked at several points, as at the joints of pillars and beams, etc.

The majority of the cast iron columns supporting the roof over the passenger platforms at Tokyo Station were broken and fell.

The main building of Ueno Station, which was one-storied and constructed of brick, was destroyed by fire. There were many wooden main buildings, sheds, or storehouses that collapsed at local stations, among which may be mentioned the reinforced concrete goods shed at the Takashima freight yard, which collapsed during the earthquake. The coal power plants and substations also sustained earthquake or fire damage in some measure.

VII. — **Rolling stock**.

Most of the rolling stock destroyed by fire was that which was standing in the station yards of Ueno, Tokyo, Shiodome, Iidamachi and Akihanohara; otherwise, the damage of the rolling stock was chiefly due to derailment and overthrow caused by the earthquake.

VIII. — **Train accidents**.

No small number of trains running or stopping at the time of the earthquake in the districts affected were derailed or overthrown, owing to the disorder of track caused by the vibration and cracking of the ground, or to landslips, or to the track being submerged. The most remarkable accident was that of a train stopping at Nebukawa Station being thrown into the sea, as previously described.

CONCLUSIONS TO BE DRAWN.

1. — The extent of damage to works and structures varies with the distance from the seismic centre, the topography and the nature of the soil of the locality affected, method and character of construction and material, shape, height and dimensions, design and execution of the work, etc.

2. — The resistance to vibration offered by embankments and fillings is very low, so that construction of any high earth dams for reservoirs and of any structures, built upon the embankment or spanning both the firm and weak strata near the earthquake zone should be done with special care in order to secure absolute security for them.

3. — Brick or masonry work generally offers low resistance to earthquake shock, and the percentage of damage to such work is rather high.

In Tokyo, some buildings of brick or masonry work of less than five storeys suffered no damage, these being built upon good ground or satisfactory found-

ation, and being properly designed and executed.

4. — The resistance to earthquake of plain concrete work seems to be nearly the same as that of brick work.

5. — In general, steel structures offer a high resistance to earthquake. The iron-framed building with reinforced concrete walls, however, has shown an excellent result, and next comes the steel frame with good brick or hard stone curtain walls. Any buildings having hollow brick or terracotta curtain walls sustained severe damage, and the walls between the windows showed huge X-shaped cracks, or else the bricks fell right out, thus exposing the frame. With iron frames of insufficient strength, the iron pillars were often found bent. In short, it seems that there were not a few iron structures whereof the rigidity had not been fully considered, and which consequently failed.

6. — In point of resistance to earthquake, reinforced concrete work comes next to iron work. Buildings, even of reinforced concrete work, where comparatively few side walls and interior partition walls had been used, or curtain walls of hollow brick work and a greater number of isolated pillars had been used, in many instances completely collapsed, or else the pillars or the joints of pillars and beams were broken. Generally, the reinforced concrete work proved excellent against fire.

7. — Wooden houses, of less than three-stories and roofed with light materials, offer a fairly high resistance to earthquake.

8. — There were many houses styled « fireproof » and yet destroyed by fire. The destruction of some of them seems to have been due to the sky light not having been made perfectly fireproof.

[625 .252]

HAND BRAKES ON GOODS TRAINS,

By E. CHOQUET,
INSPECTOR GENERAL OF THE BELGIAN STATE RAILWAYS.

Figs. 1 to 5, pp. 225 to 236.

The problem of hand brakes for goods trains consists in determining, for a train of any composition, the weight which must be braked in order that stops may be made from any given speed within a certain distance, the gradients of the line being taken into consideration.

Theoretically, this problem is very simple. It is only necessary to apply the laws of motion.

The difficulties commence when one has to insert in the equations the numerical values pertaining to the particular case under examination.

These numerical values depend, however, on the state of the weather, the vigilence of the train crew, adjustment of the rigging, etc.

In order in the first place to solve the problem theoretically, we will adopt the following notation :

P (tons) = the total weight of the train, engine and tender included;

P′ (tons) = braked weight, engine and tender included;

$p = 100 \times P' \div P$ = proportion of the train braked per cent;

V or v = initial speed of the train in kilometres per hour and metres per second respectively;

i = gradient in millimetres per metre;

E (in metres) = stopping distance;

r (kgr. per t.) = resistance to motion of the axles which are not braked;

R (in kgr.) = total retarding force for the train, engine and tender included;

ρ (kgr. per t.) = $R \div P$ = retarding force per ton of the train, engine and tender included;

b (kgr. per t.) = $R \div P'$ = retarding force per ton of braked weight;

a (kgr. per t.) = limiting value of adhesion between wheel and rail.

If we consider a train weighing P tons, we deduce the following general equation :

$$\frac{1}{2} 1\,000 \frac{P}{g} (v_1^2 - v_0^2) = (Pi - R)\,E,$$

$$\frac{1\,000}{2 \times 9.81 \times 3.6^2} (V_1^2 - V_0^2) = (i - \rho) \times E.$$

As the initial speed, $V_0 = V$; and the final speed, $V_1 = o$.

We therefore have :

$$\rho = 3.93 \frac{V^2}{E} + i.$$

However, we have not included the rotary inertia of the revolving masses, which is not always negligible.

We will represent by n the ratio which the rotary inertia of the wheels of any vehicle bears to the linear inertia of the same vehicle (including the mass of the wheels).

If :

P_t (in t.), is the total weight of the vehicle, wheels and loaded included;

P_r (in t.), the weight of a pair of wheels;

K, the number of pairs of wheels per vehicle;

R (in m.), the radius of the tread of the tyre;

R′ (in m.), the radius of gyration of a pair of wheels;

v (in metres per second) or V (km. per hour), the speed of the vehicle;

ω, the corresponding angular velocity of the wheel.

$$\omega = \frac{v}{R} = \frac{V}{3.6\,R}.$$

The linear inertia of the vehicle is, as we have just seen :

$$3.93\ V^2P_t \text{ (kgr.-m).}$$

The rotary inertia of a pair of wheels is equal to

$$\frac{1}{2}\frac{1\,000}{g} P_r \times \omega^2 R'^2 =$$

$$= \frac{1\,000\ V^2}{2 \times 9.81 \times 3.6^2} P_r \frac{R'^2}{R^2} =$$

$$= 3.93\ V^2 \frac{R'^2}{R^2} P_r.$$

The total inertia of the vehicle will therefore be :

$$3.93\ V^2P_t + K \times 3.93\ V^2 \frac{R'^2}{R^2} P_r =$$

$$= 3.93\ V^2P_t\left(1 + \frac{KP_r}{P_t}\frac{R'^2}{R^2}\right).$$

From which

$$n = K \cdot \frac{P_r}{P_t} \cdot \frac{R'^2}{R^2}.$$

For any given pair of wheels, the value of R′ may be determined by separately considering the various parts (axle, wheel boss, spokes, rim and tyre).

However, it is necessary for wheels of the same type to check the thickness of the tyres.

As the tyre is the part of the wheel which is at the greatest distance from the axis of rotation, this will have the greatest influence, and therefore the rotary inertia of a pair of wheels in which the tyres have reached the scrapping size is not more than half the value that it would have in the case of wheels with new tyres.

In this way, for any particular vehicle the ratio n varies widely in accordance with the thickness of the tyre.

In the case of vehicles of different types carrying the same load, it will also vary in accordance with the tare and the number of pairs of wheels. It will be seen that this difference may be considerable, ranging from the four wheel covered wagons with a brakesman's box, to eight wheel flat wagons (without bogies) for carrying heavy stones.

For vehicles of the same type with tyres of the same thickness, n may vary largely in accordance with whether the wagon is empty or fully loaded : for a 20 t. coal wagon, unbraked, the loaded weight is more than three times the empty weight.

It follows that for an empty 20 t. coal wagon with new tyres, n is six times as great as for the same wagon when loaded and with tyres worn to the minimum thickness.

It may be also mentioned that the composition of trains does not always consist of various types of loads in the same proportion, as it will be frequently found that a train is made up entirely of fully loaded wagons or entirely of empty wagons.

Under these conditions, it will be seen

that it is very difficult to decide what is to be taken as the average value for n.

As the result of calculations made for certain freight vehicles of the Belgian State Railways, the value of n was found to vary from 2 % in the case of heavily loaded wagons with worn tyres, to 20 % for empty wagons with new tyres.

This uncertainty is all the more serious in that it is affected by the term V^2, which, as we shall see later on, is very important for gradients for less than 9 mm. per metre, that is to say in the majority of cases.

We have taken for the value of n, 8 % as adopted in the French rules, so that in the fundamental equation, we may replace M by 1.08 M, which gives us :

$$\rho = 1.08 \times 3.93\,V^2 \div E + i = \frac{4.24\,V^2}{E} + i.$$

We have assumed that R, the total retarding force (and consequently ρ) remains constant throughout, the whole of the brake application. We know, however, that this is not the case.

Experiments, especially those made by Bochet and Poirée, Westinghouse and Douglas Galton, and Wichert, have shown that the friction between brake blocks and tyres at the speeds met with in railway practice obeys two laws, which both have their effects.

The tangential force increase as the speed diminishes, and also diminishes as the time or distance of the brake application increases.

These two laws are also affected by a third consideration : the state of the surfaces in contact which are affected by weather conditions, such as, snow, fog, frost, fine rain, dead leaves, coal dust, mud from level crossings, sand from the engine sand boxes or ballast left on the rails by the platelayers, dirty rails, etc.

The law of the variation of the coefficient of friction as a function of the speed has been deduced by Douglas Galton from a large number of tests up to about 96 km. (60 miles) per hour. However, he does not seem to have taken sufficient account of the state of the rail. Moreover, it is very difficult to group the results of tests dealing with rails in the same condition, for the reason that there is no means of determining this, and one can only state that a rail is « somewhat damp », for example.

However, one can determine the maximum value on the one hand for very dry rails and the minimum for the case of slippery rails, as has already been done by Bochet in the conclusions which he draws from his tests of 1858 and 1861.

A large number of formulæ have been proposed to embody the results obtained by Douglas Galton and by Wichert [1]. We will adopt that given by Mr. De Blieck, chief engineer of the Belgian State Railways :

$$\frac{f}{1\,000} = \frac{14.520}{V + 44},$$

in which f represents the tangential force in kilograms due to a force of one ton exerted by the brake block on the tyre.

The second law on the other hand appears to have been very little investigated. The only figures which are available deal with periods of application which are much too short. It may be mentioned that the trials of Douglas Galton were carried out exclusively on passenger trains fitted with the Westinghouse brake on all wheels.

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[1] Bochet's figures can hardly be used in connection with present day methods of braking, since they deal with vehicles in which the wheels were prevented from rotating, that is to say, that the tyres skidding on the rail and not rubbing against the brake-blocks.

Under these circumstances, the time taken in stopping is in most cases less than half a minute. In the case of freight trains this is a very different matter. The duration of the brake application may often be more than twice this, and the length of times the brakes are applied on some long gradients may be as long as ten minutes or even much greater than this.

The formulæ given by some authorities to include this effect, due to prolonged application, in calculations dealing with passenger trains fitted with the Westinghouse brake cannot therefore be used, since they give values of f for periods of application of the brakes less than those which are met with in the case of freight trains.

It may be asked moreover if it is the length of time during which the application is made rather than the distance over which the application extends, which should be taken as the independent variable.

In accordance with Wichert's experiments, it would appear that this influence, which has a considerable effect at the commencement of the application, rapidly loses its importance.

However, this may be, the large number of tests which have been made since 1879 (the date at which Douglas Galton's experiment showed the action of the brake in a clear and indisputable manner) have invariably shown that where the brakes are fully applied, the tangential force plotted against the speed is represented by an horizontal line which finishes up at the latter part of the application by a curve which rises very rapidly.

Therefore in the equation for the stopping distance, the figure which represents a coefficient of friction which varies with the speed may be replaced by an equivalent constant value, that is to say, a value which has the same effect in the same distance with the same normal pressure.

This pressure on the brake-blocks also gives rise to some uncertainty.

If the brakesman does not exert a continual pressure on his hand wheel, the brake will tend to release itself.

If on the other hand he puts his brake on as hard as possible, he will lock the wheels and cause skidding. He therefore will, in order to avoid the production of flat tyres, have to release the brake and re-apply it. It is therefore very difficult to determine what is the constant and continuous pressure which is equivalent to the variable and intermittant forces which are exerted during the brake application.

Moreover, modern practice is to fit goods engines with compressed air brakes which act on all the wheels of the engine, except bogie and truck wheels, and also upon those of the tender. If the brake is not of the direct acting type, the pressure in the cylinder inevitably decreases as the length of the application increases, because the driver does not release the brake in order to recharge the auxiliary reservoirs till as late as possible. Moreover, this decrease in the pressure may be considerable if the leather packing of the pistons in the brake cylinders is not kept in good repair.

Finally, in order to determine the force exerted by the brake-blocks in the tyres, one starts with the pressure in the cylinder or the force applied at the hand wheel, and determines, by consideration of the leverage of the rigging, the theoretical force exerted on the brake-blocks. As a rule no allowance is made for the efficiency of the rigging, although the value of this appears to differ widely from unity.

There is no doubt that experiments

made by the means of « crushers » [1] and pressure recording devices to determine the actual pressure exerted by the brake-blocks on the tyres under working conditions will give us figures which may be used to check our calculations.

In the foregoing it has been supposed that we have only to deal with a uniform material, both for the brake-blocks and for the tyres.

However, it has been found in the United States, in the application of the continuous brake to long freight trains, that very appreciable differences are experienced in the same train, in which all other factors are equal, merely by the difference in the nature of the cast iron used for the brake-blocks on adjacent vehicles. It would appear that sufficient attention has not been given to this point.

The number of brake-blocks used, however, constitutes a source of expense which calls for our very close attention.

In the year 1922, the Belgian State Railways used 250 000 brake-blocks for wagons, carriages, engines and tenders, costing in all 2 million francs.

In order to determine the tangential force to be taken in our calculations, we must also take into account the length of the stopping distance at the same initial speed, that is to say, it is necessary to adopt different average values according as to whether a stop has to be made in 1 000 m. (1 100 yards) (and sometimes more) on a falling gradient on the level in a distance of 800 m. (880 yards), or on a rising gradient in a still less distance.

It will be seen therefore that we cannot determine the value *b*, that is to say, the retarding force per ton of braked weight, merely by calculation, and we must rather determine this from the results of tests, relying merely upon calculations to check and co-ordinate these results.

The value of E (length of the stop) also gives rise to some uncertainty. One cannot take the distance run from the moment when the brakesmen receive the signal to apply the brakes, since the equation has been based on the assumption that all the brakes are in action throughout the length of the stop.

However, if one could agree upon the time necessary for a brakesman to fully apply the brakes after the moment that he receives the signal, it is, however, impossible to assume that the signal given by the engine whistle at the front of the train will always be immediately acted upon by the brakesman situated at the rear of a long freight train, which is sometimes more than half a kilometre (550 yards) from the engine.

This is perhaps the weakest point in our present day system of hand brakes on freight trains. In most cases the brakesman, not having heard the signal given on the whistle, receives his first intimation by the shock produced by the brake application at the front of the train. He then tries to sum up the situation, looking out first on one side and then on the other, and thus loses valuable time. This loss of time is equivalent to the reduction in the distance available for making a stop equal to $V \div 3.6$ m. for each second lost, or at the usual speed for freight trains, of 45 km. (28 miles) per hour, this equals 12.5 m. (41 feet) per second.

On the other hand, when the engine is fitted with the Westinghouse brake, the driver cannot immediately make a full application. Regulations lay down that

[1] This term is used in the United States for small pieces of soft copper placed between the brake block and the tyre, which, when a test application of the brake is made, are compressed, and the force between the brake-block and the tyre can be determined by observing the amount of deformation.

he must in the first place apply the hand-brake on the tender so as to bring all the buffers of the train into contact, and it is only when he has done this that he can apply the air brake.

On the Belgian State system, the outer signals have been or will be replaced by distant signals which can be passed in the « on » position, these being proceded by five white posts 50 m. (164 feet) apart and marked 5, 4, 3, 2, 1, in black figures. These distant signals should be visible at a distance of 300 m. (330 yards).

Under these circumstances, it appears sufficient to suppose that the length of stop to be taken into consideration in the calculations is the distance between the distant signal and the stop signal.

At a speed of 45 km. (28 miles) per hour, this preliminary distance will be covered $300 \div 12.5 = 25$ seconds, which is ample time, provided the driver sounds his whistle in time, and the brakesmen hear it and act upon it without delay.

In this case the human factors of discipline and alertness must be taken into consideration, and these can hardly be included in an equation.

Visibility at 300 m. is of course reduced in foggy weather, but under these circumstances drivers run with caution, that is to say, at a lesser speed. Moreover, at 250 m. (275 yards) he is informed of the position of the distant signal by the first of the five posts, and if he cannot see the signal, he should then apply the brakes and give the signal to the brakesmen.

As regards the influence of the gradient i (mm. per m.) it should be noted that, as the train has been dealt with as a particle concentrated at one point, it is the initial and final position of its centre of gravity which must be taken into consideration.

For trains of more than 500 m. (550 yards) in length assisted by a banking engine at the rear, the centre of gravity will be about 250 m. from the front of the first engine, and it may be necessary to make corrections if the gradient varies appreciably in the length occupied by the train when the front of the engine is opposite the distant signal.

Figures 1 and 2 illustrate two cases of this kind.

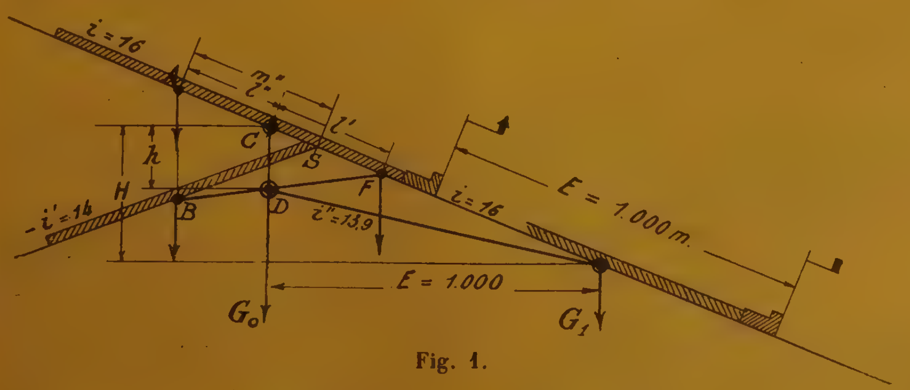

Fig. 1.

If the gradient is uniform,

$$i = \frac{H}{E} \times 1\,000,$$

and

$$\rho = \frac{4.24 \times V^2}{E} + i.$$

If

$$i = 16,\ V = 45 \text{ and } E = 1\,000,$$

we have :

$$\rho = \frac{4.24 \times \overline{45}^2}{1\,000} + 16 = 8.6 + 16 = 24.6.$$

The necessary braked percentage is given by :

$$\frac{p}{100} = \frac{\rho - r}{a - r}.$$ (See p. 230.)

If : $a = 100$ and $r = 3$,

$$p = 1.03 \times (\rho - 3) =$$
$$= 1.03 \times (24.6 - 3) = 22.2.$$

If the line changes gradient at S, the diagram shows that the centre of gravity of the complete train at the moment when the brakes are fully applied (when opposite the distant signal), decreases to h, and the equivalent gradient becomes :

$$i'' = \frac{H - h}{E} \times 1\,000.$$

The train is devided by the point S into two parts. If m'' is the distance of the centre of gravity of the rear portion to the summit, we have :

$$AB = m'' \times \frac{i + i'}{1\,000}.$$

If l' and l'' are the distances between the centre of gravity of the whole train and the centres of gravity of the two parts situated in front and behind the centre of gravity of the whole we have :

$$CD = AB \times \frac{l'}{l' + l''} = h.$$

It may be pointed out, in view of the diversity of the various vehicles which make up the train (engines, tenders, wagons and brake-vans) and of their loading, the weight per foot run varies widely, and therefore the centre of gravity need not be at the centre of the length of the train, nor is this so in the case of the two portions situated in front and behind the centre of gravity of the whole.

Let us take as a numerical example :

$$i' = 14, \text{ and } m'' = 150,$$

$$AB = 150 \times \frac{16 + 14}{1\,000} = 4.50.$$

If $l' = 120$ et $l'' = 140$:

$$CD = 4.50 \times \frac{120}{120 + 140} = 2.08 = h.$$

The value of the equivalent gradient to be taken into consideration is therefore :

$$i'' = \frac{16 - 2.08}{1\,000} \times 1\,000 = 13.9,$$

and the retarding force which is required is reduced to :

$$\rho'' = 8.6 + 13.9 = 22.5,$$

a decrease of $2.08 \div 24.6 = 8\ 1/2\ \%$.

The proportion of braked weight required to stop in a same distance of 1 000 m. (1 100 yards) is given by :

$$\frac{p''}{100} = \frac{\rho'' - r}{a - r},$$

or if

$$a = 100 \text{ and } r = 3,$$
$$p'' = 1.03 \times (22.5 - 3) = 20.1,$$

in place of 22.2, that is to say, a decrease of $2.1 \div 22.2$ or 9 %.

If we retain the original proportion p, and therefore the original retarding force per ton ρ, the length of the stop will decrease from 1 000 m. to :

$$E'' = \frac{4.24\ V^2}{\rho - i''} =$$
$$= \frac{4.24 \times \overline{45}^2}{24.6 - 13.9} = 800 \text{ m. (880 yards)},$$

a decrease of 200 m. (220 yards), or 20 %.

In the case of figure 2, if the train is on a continuous level line, and :

$$E = 800; \quad V = 45; \quad i = 0,$$

the retarding force per ton will be :

$$\rho = \frac{4.24 \times \overline{45}^2}{800} + 0 = 10.7.$$

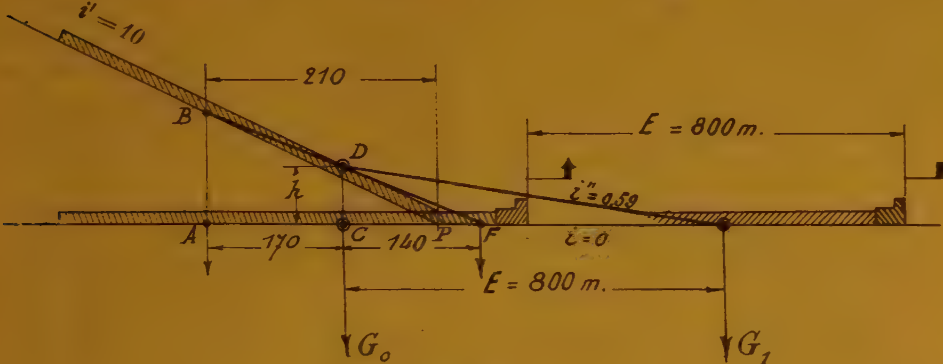

Fig. 2.

The braked proportion necessary will be with $a = 100$ and $r = 3$:

$$p = 1.03 \times (10 - 7) = 7.9.$$

If the level line is preceded by a down gradient i' of 10 mm. per m., the level line should be replaced by a down gradient of

$$i'' = \frac{h}{E} \times 1\,000.$$

If the centres of gravity of the front and rear portions of the train are 140 m. (153 yards) and 170 m. (186 yards) respectively from the centre of gravity of the whole, and if the distance from the foot of the slope P to the centre of gravity of the rear portion is 210 m. (230 yards), we have as in the preceding case :

$$BA = 210 \times \frac{10}{1\,000} = 2.1$$

$$CD = h = 2.1 \times \frac{140}{140 + 170} = 0.948,$$

and

$$i'' = \frac{0.948}{800} \times 1\,000 = 1.18.$$

The necessary force becomes :

$$\rho'' = 10.7 + 1.18 = 11.88$$

in place of 10.7, an increase of :

$$1.18 : 10.7 = 11\ \%.$$

The new proportion necessary to produce the stop in the original distance of 800 m. (880 yards) will become, with

$$a = 100 \quad \text{and} \quad r = 3,$$

$$p = 1.03 \times (11.88 - 3) = 9.15$$

in place of 7.9, an increase of 1.25 to 7.9 or 16 %.

If we retain the original braked proportion of 7.9 and consequently the original retarding force per ton of 10.7, the length of the stop will increase from 800 m. to

$$E'' = \frac{4.24 \times \overline{45}^2}{10.7 - 1.18} = 902$$

an increase of 102 : 800 = 13 %.

These calculations are sufficient to show that it is a difficult matter to draw up from first principles the values to be

used in the equation dealing with a particular case in which it is required to calculate the total retarding force R (kgr.) or the retarding force per ton ρ necessary to stop a train running at a speed V on a gradient of i (mm. per m.) in a distance E (in m.).

We shall now see that the same is true in the case of the equation which gives a retarding force which may be realised in a train of which a given proportion is braked.

For a train of 100 t. (including engines and tenders) we should have from first principles :

$$100\rho = pb + (100 - p)r. \qquad (2)$$

It may be pointed out that b represents the average retarding force per ton of braked weight of the whole of the train (engine, tender, brake-van and brake wagons).

It is assumed that

$$a \geqslant b,$$

that is to say, the adhesion of the tyre on the rail is at the least equal to the tangential force exerted by the brake-blocks on the tyres. Otherwise b must be replaced by a in the equation. It is useless in fact to increase the tangential force exerted by the brake-block on the tyre (either by increasing the normal pressure or by adopting a special mixture of cast iron) if the adhesion on the rail is thus made to become less than this tangential force, the effect will merely be to cause slipping.

It may be pointed out in passing that the decrease in the retarding force which is caused by the wheels skidding is less than one might at first imagine.

Although it is true that the coefficient of friction between the tyre and rail when the wheel is skidding is less than that between the brake-block and tyre at the same surface velocity, it should not be overlooked that the reaction between the rail and tyre is equal to the total load carried on the axle (including the contents of the wagon) while the normal pressure between the brake-block and tyre is as a rule about two thirds of the actual load when the wagon is empty.

However, one cannot allow skidding to take place because of the risk of causing flat tyres.

For a long time, however, the rule was to skid the wheels, but at this time (about 1865) the load per wheel was hardly one third of the load at the present day, which is now as much as 7 1/2 t. per wheel. With present day rolling stock one may assume that the design is such that

$$b \geqslant a.$$

We may therefore write :

$$100\rho = pa + (100 - p)r$$

or

$$100\rho = p(a - r) + 100r.$$

We see then that ρ is dependent on the value of a, which (as we have shown above) is a very uncertain factor, and also upon a value of r, which varies with the speed.

The formulæ which have been proposed to determine the value of r, in kilograms per ton, of the total weight of the vehicle are numerous and differ widely one from the other. This can hardly be otherwise since resistance depends on factors which not only depend on the surface offered to the effect of air resistance but also upon others which only depend upon the weight.

The resistance per ton of a 20 t. coal wagon obviously will not be the same when loaded as when empty.

On the other hand, the value of r to

be taken is an average between that which corresponds to the initial speed and the speed immediately before coming to rest.

Moreover, the various authorities are not in agreement as to the method of calculation to be employed in determining this average value.

The value of r may, however, be of considerable importance in the case of very long trains running on relatively level lines.

It may be asked if it is permissible to add the value of r to that of b for the wheels which are braked.

However, as we have shown above, in the case of well designed rigging, b is always greater than or equal to a, and it is of little importance by what means the total value of b is obtained.

In the case of locomotives, the value of r is considerable greater, but it is well, if one aims at accuracy, to proceed with the determination of the retarding force of the engines and tenders and to show this as a separate term in the calculations, especially in cases where the direct air brake or the method of reversing the engine under steam is used with the employment of effective sanding gear operating on all the braked wheels in the direction of running.

In calculating the brake % (p), certain errors may arise from the fact that some of the brakesmen are not carrying out their duties or only do so with a certain amount of delay, or that certain brakes may be out of order with broken brake-blocks, etc.

In view of these uncertain factors, it appears well to deal with this question in another way. Instead of attempting to determine by calculation unknown values which we can never accurately obtain, it appears more practical to draw diagrams which give in a simple manner the relationship between all these unknown factors in all possible cases which may occur in practice. In this way, without having to make any lengthy calculations for every possible case, one may, in cases where a stop signal has been passed for example, quickly and accurately investigate what may have probably happened by successively giving to V, E, p, ρ, a and r a series of simultaneous values which will satisfy the actual observations, the statements of witnesses, the condition of the rolling stock and of the road, state of weather, etc..

Graphical tables would give us the same information, but these tables are more suitable when one is dealing with complicated functions (transcendental, logarithmic, exponential, etc.) and they do not give the same advantage when one is dealing with simple functions such as in our two fundamental equations.

On the other hand diagrams allow one to see at a glance how certain variables are effected by the variation of other variables.

Before showing how these diagrams are constructed, we will determine the values to be obtained from our two equations.

The first gives us the brake power necessary under the conditions laid down as to speed, gradient and length of stop. The second gives us the brake power obtained with different proportions of braked vehicles and under different conditions of adhesion and train resistance.

If we make the required retarding force equal to the retarding force which may be obtained, we have :

$$\frac{4.24\ V^2}{E} + i = \rho =$$

$$\frac{p}{100}a + \frac{100 - p}{100}r.$$

The problems which can be solved by

means of this equation are numerous. We give a few examples.

One can, given the speed allowed on any particular portion of the line and the distance in which it is required to stop, determine the number of wagons which must be braked.

One can also calculate what the initial speed was when one knows the stopping distance, the gradients and the proportion of braked wagons, so that in cases where a stop signal has been passed, it can be seen whether the driver has exceeded the maximum speed. (The engines of the Belgian State Railways are not provided with speed recorders.)

If we know the distance in which the stop is made, the initial speed, the gradient and the proportion of the train which is braked, we can find what are the simultaneous values of a and r which allow the necessary retarding force to be obtained.

If one knows the distance over which the brakes have been applied and the gradient, and also the initial speed, one can determine what proportion of the train was braked, and by comparing this with the total braked weight, one can ascertain whether the train staff have made prompt and complete use of the brake power at their disposal.

When we have no data for the values of r and a, we shall adopt provisionally and with reservations :

$$a = 100 \text{ (kgr. per t.)},$$
$$r = 3.$$

If an examination of special circumstances in any particular case leads us to increase or decrease these values, calculations must be worked out afresh.

For example, in frosty weather, it is certain that $a = 100$ is too high a figure.

The values $a = 100$ and $r = 3$ may be considered as average values, and it follows that results obtained by these assumptions may be useful, merely as a first approximation to be examined by further investigation.

For a given train, that is to say, where the proportion p (%) is known, the value of the necessary retarding force per ton is given by :

$$\rho = \frac{p}{100}(a - r) + r$$

that is, for $a = 100$ and $r = 3$:

$$\rho = 0.97\,p + 3.$$

Conversely, if ρ is given, the necessary proportion will be :

$$p = 100\,\frac{\rho - r}{a - r}.$$

that is, for $a = 100$ and $r = 3$:

$$p = \frac{100}{97}(\rho - 3) = 1.03\,(\rho - 3).$$

Putting in the value for ρ :

$$p = 100\,\frac{4.24\,V^2 \div E + (i - r)}{a - r}, \qquad (3)$$

that is, for $a = 100$ and $r = 3$:

$$p = \frac{4.37\,V^2}{E} + 1.03\,(i - 3).$$

We can also find from the results of a test with a given train what is the value of the average retarding force per ton of the braked vehicles :

$$b = \frac{100}{p}\left(\frac{4.24\,V^2}{E} + i\right) - \frac{100 - p}{p}\,r.$$

This equation can be written as follows :

$$b = \frac{100}{p}\left(\frac{4.24\,V^2}{E} + i - r\right) + r. \qquad (4)$$

Having found in the course of the test

the values of E, i, V and p, it is only necessary to give to r suitable values in accordance with the speed and nature of the rolling stock and the state of the weather in order to obtain the value of the retarding force, which, however only represents the average for the whole of the various braked wheels (engines, tenders, brake-vans and wagons) and for speeds decreasing from the beginning of the brake application up to the moment of stopping.

In order to separately determine the value of the retarding force of engines and tenders, the same formula may be used. This is simplified when, as most frequently happens, all the axles are braked.

In this case, $p = 100$, and consequently:

$$b = \frac{4.24 \times V^2}{E} + i.$$

The retarding force b includes the whole of the resistance of the internal mechanism, air resistance, rolling resistance, etc.

One can thus easily determine the values of V and E on a known gradient i.

In the case where the engine is not fitted with a speed indicator, the method of counting the rail joints (or even the revolutions of the wheel) will give a sufficiently accurate result. In order to obtain the speed in kilometers per hour, it is only necessary, as is well known, to count the joints for $3.6 \times L$ seconds, where L equals the length of the rail in metres, or even to count one half or one third of this number of seconds and to multiply the number of joints passed over by 2 or 3, etc. For example, with rails 18 m. (59 feet) in length and a speed of 45 km. (28 miles) per hour, it is necessary to count 15 joints in 21.6 seconds, or 30 joints in 43.2 seconds. The distance necessary to make this count being $L \times V$ in metres. It will be seen that 540 m. (590 yards) is sufficient for this purpose.

If one counts the number of revolutions of the wheel in place of the number of rail joints, and if D (in metres) is the diameter of the wheel, the number of seconds will be $3.6 \times \pi D = 11.3\ D$ in place of 3.6 L.

It may be mentioned that the values thus found for b will be too high for the reason that the stop so made is shorter both as regards time and distance run than would be realised when the engine is hauling a train.

These tests may be quickly repeated and thereby allow the comparative figures to be obtained for the hand-brake, ordinary air-brake, rapid acting brake, direct acting brake, and for the method of controlling the train by reversing the engine. They allow an exact determination to be made of the time and distance lost by the progressive application of these various methods of braking.

One may also investigate the influence of the load of the tender. The weight on the tender axles may, in fact, for modern engines vary by more than 30 t., depending on whether the tanks are full or almost empty.

The above formulæ are simple, but their repeated application is a lengthy and cumbersome process. They may be replaced with advantage by the diagrams shown in figures 3 and 5.

That shown in figure 3 is based on the equation

$$\rho = \frac{4.24 \times V^2}{E} + i,$$

written in the form

$$E = \frac{4.24\ V^2}{\rho - i}.$$

If we know the value $\rho - i$, it will be

seen that E will be represented by a series of parabolas passing through the origin.

By marking off on the abscissa values of V^2 in place of values of V, the parabolas will become straight lines passing through the origin.

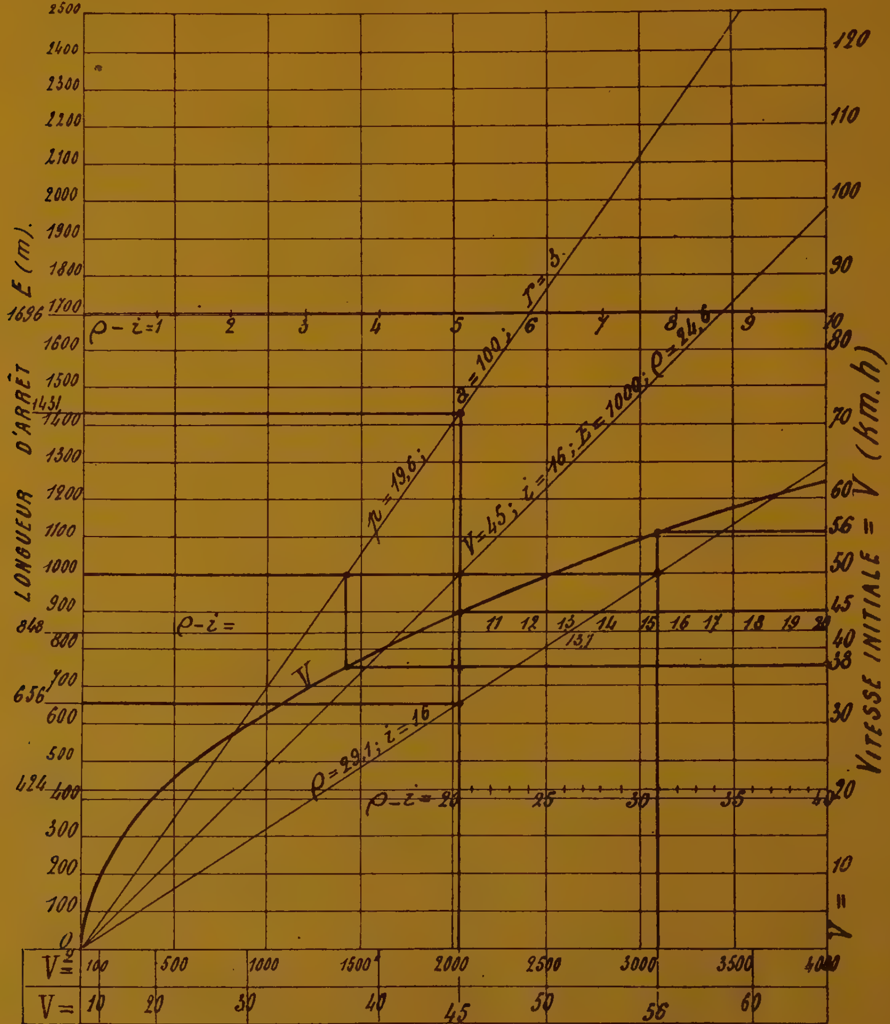

Fig. 3. — Diagram of speeds V and stopping distances E and the retarding force per ton ρ.

Note. — To be reduced on millimetre squared paper to a scale of $V^2 = 100 = 5$ mm.; and $E = 100$ (m) $= 10$ mm.

For

$$E = 424,$$

it will be seen that

$$\rho - i = \frac{V^2}{100}.$$

On a horizontal line at a height $E = 424$, one can therefore mark off distances representing $\rho - i$, and thus draw lines corresponding to all the values of $\rho - i$. To obtain a more convenient scale, this has also been done for

$$E = 2 \times 424 = 848$$

and for

$$E = 4 \times 424 = 1\,696.$$

The parabola giving V as a function of V^2 has also been drawn, and the scale of V is marked on the right hand side of the diagram. Moreover, as V is given as well as E, it is only necessary to follow the horizontal line from the scale of V to the point where it meets the parabola, and to then proceed vertically to the point where it meets the horizontal E.

By placing a rule from this point to the origin, one can read the value of $\rho - i$ at the intersection of this line with one or other of the three scales of $\rho - i$.

If the value of i is known, one can deduce the value ρ, which allows us to pass on to the diagram given in figure 5 which is based on the equation :

$$\frac{p}{100} = \frac{\rho - r}{a - r}.$$

The base line of this diagram is marked to show the proportion of braked weight p, figured from left to right. The vertical scale on the right hand side represents the values of a (or b) and the vertical scale on the left hand side the values of ρ and of r.

These four values are to the same scale (kgr. per t.).

The diagram in figure 4 shows that :

$$\frac{OP}{OD} = \frac{RP - OA}{DB - OA},$$

that is to say :

$$\frac{p}{100} = \frac{\rho - r}{a - r}.$$

It is therefore only necessary to mark off on the left hand vertical scale the value of r, and on the right hand vertical scale the value of a, and then to join these two points by a straight line in order to obtain the values of ρ as a function of p, or *vice versa.*

If on the other hand one starts by knowing the values of ρ and p, these values from the co-ordinates of a point through which can be drawn a straight line which cuts on the two vertical scales two simultaneous values of a and r which will give the necessary retarding force with the particular proportion of braked weight.

One can in this way rapidly determine without any calculation all the possible and probable combinations of conditions as regards the weather, the speed and type of rolling stock which may be met with.

It may be mentioned that the two calculations represented by these diagrams are strictly accurate, the only risk being in the values which are assigned.

For example, before making use of the value of E, one should be certain that this has been accurately determined, that is to say, whether any error has been made in the distance run before a full application of the brakes has been made.

In order to obtain a convenient scale to read off the diagrams without having to draw them out to an inconvenient size, the scale giving a proportion of braked weight has been halved. The scale of values of a plotted on the right of the diagram has been doubled, and it will

be seen that the numbers give $a + r$ instead of a, as shown in figure 4 :

$$EG = \frac{OA + DB}{2} = \frac{a + r}{2}.$$

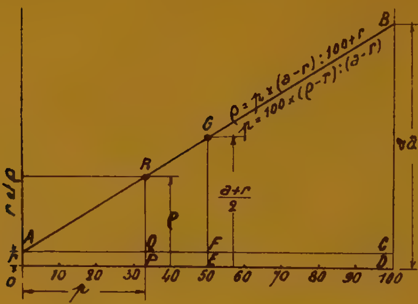

Fig. 4.

The advantage of the diagrams, as we have already said, lies in the fact that they permit one to read off the value of any of the variables under any set of conditions.

For example, if the value of $\rho - i$ is known, it will be seen from the corresponding sloping line which is the simultaneous values of V and E which may give the necessary retarding force on the gradient under consideration.

For any stipulated stopping distance one can easily see by pivoting a ruler from the origin of figure 3 how $\rho - i$ must be varied if one wishes to increase the speed, and in the same way if one wishes to reduce the brake power (that is to say, $\rho - i$), one can see how much the speed must be reduced if the stopping distance is to remain the same.

We will take as an example a goods train on the Luxemburg Railway (Schaerbeek-Namur-Arlon) hauled by a locomotive of the 36 class and assisted at the rear by a locomotive of the 37 class, running at the maximum authorised speed of 45 km. (28 miles) per hour on a continuous gradient of 16 mm. per m.

The train consists of 180 units of load corresponding to 990 t. (the unit of load being approximately 5.5 t.).

It is laid down in the *regulations* that one sixth of the weight of the train must be braked; the assisting engine is taken as being equal to 8 braked units in the calculation, and the train engine is excluded.

The braked weight in the train will therefore be $180 \times \frac{1}{6} - 8 = 22$ units braked, which are operated by five men, namely, four brakesmen and the chief guard.

All the wheels of the engines and tenders are operated on by the Westinghouse brake, either ordinary or direct acting, with the exception of the truck wheels of the 37 class engine.

Under these conditions the value of the braked percentage is as follows, the unit of weight being the tonne.

I. — *Total weight of the train.*

Train engine, 36 class	104.2	
Tender (empty)	22.6	
Water . . . . 24 000 litres.		
Coal . . . . 7 000 kgr.		
Weight of coal and water.	31.0	
Train engine and tender (in working order)		157.8
Engine, 37 class, at rear of train.	89.7	
Tender, — — — .	53.6	
Assisting engine and tender (in working order).		143.3
Total weight of both engines. . .		301.1
Train : 180 units of 5.5 t.		990.0
Total weight engines and train. . .		1 291.1

II. — *Total braked weight.*

Engine and tender, 36 class (tender empty).		126.8
Engine, 37 class (less truck wheels).	77.8	
Tender for 37 class (empty)	22.6	
Engine and tender, 37 class (tender empty).		100.4
Braked weight of the two engines and tenders		227.2
Braked weight of the train : $22 \times 5.5 =$		121.0
Total braked weight, engines and train.		348.2

The percentage braked is therefore :

$$p = 100 \times 348.2 \div 1\,291.1 = 26.9\ (\%).$$

It may be mentioned in passing that of the total braked weight the proportion due to the engines is :

$$227.2 \div 348.2 = 65\ (\%),$$

while their proportion of the total weight is :

$$301.1 \div 1\,291.1 = 22.5\ (\%).$$

We have thought it well in reckoning the braked power of the tenders to assume that they are empty, seeing that in practice it may happen that engines may be run with the coal and water reduced to almost negligible quantities, and also on the other hand the rigging and brake cylinders should be so proportioned as not to cause skidding of the wheels when the tenders are empty.

It may be pointed out that although this may make a marked difference as regards the braked weight, the effect of the coal and water is negligible when considering the total load.

As the coal and water are roughly $2 \times (24 + 7) = 62$ t., their proportion of the braked weight will be :

$$62 \div 348.2 = 18\ (\%)$$

but only $62 \div 1\,291.1 = 4.8\ (\%)$ of the total weight.

We will assume for the absolute stopping distance a length of 1 000 m. (1 100 yards), which is that between the distant signal and the stop signal, in this way allowing the train crew the whole of the distance over which the distant signal is visible (300 m. or 330 yards as a minimum) in which to apply the brakes.

The diagram given in figure 3 shows that a speed of 45 km. (28 miles) per hour,

$$\rho - i = 8.6;$$

which gives :

$$\rho = 8.6 + 16 = 24.6\ (\text{kgr. per t.}).$$

On the diagram given in figure 5, we take the point where :

$$p = 26.9; \quad \rho = 24.6$$

through which to draw the straight line, which cuts off on the vertical scale at the left hand side, the values of r, and also on the scale on the right hand side values of $a + r$ which gives us the value of ρ which we require.

The value of r, for a given speed of 45 km. per hour, only varies in accordance with the atmospheric conditions (strong wind, severe frost, etc.), and the nature and loading of the wagons. As extreme values : $r = 2$ or $r = 6$, within which limits it is certain that the values met with in practice will lie, and from the diagram we have for these respectively :

$$a + r = 88 \quad \text{or} \quad a + r = 81;$$

which gives us finally :

$$a = 86 \quad \text{or} \quad a = 75,$$

which are satisfactory values, except under exceptional circumstances, of frost, snow, drizzling rain or dead leaves.

If we take the average values $a = 100$ and $r = 3$, the diagram in figure 5 gives us :

$$\rho = 29.1\ (\text{kgr. per t.}).$$

If we turn to diagram in figure 3, by drawing the sloping line passing through the origin and through the point :

$$29.1 - 16 = 13.1$$

from one or the other horizontal lines represented $\rho - i$, we can read off all the various initial speeds with the corresponding stopping distances which would be obtained with the retarding force

given by $\rho = 29.1$ (kgr. per t.). For example, we see that for a speed of 45 km. per hour, we can stop in the shorter distance of 656 m. (717 yards).

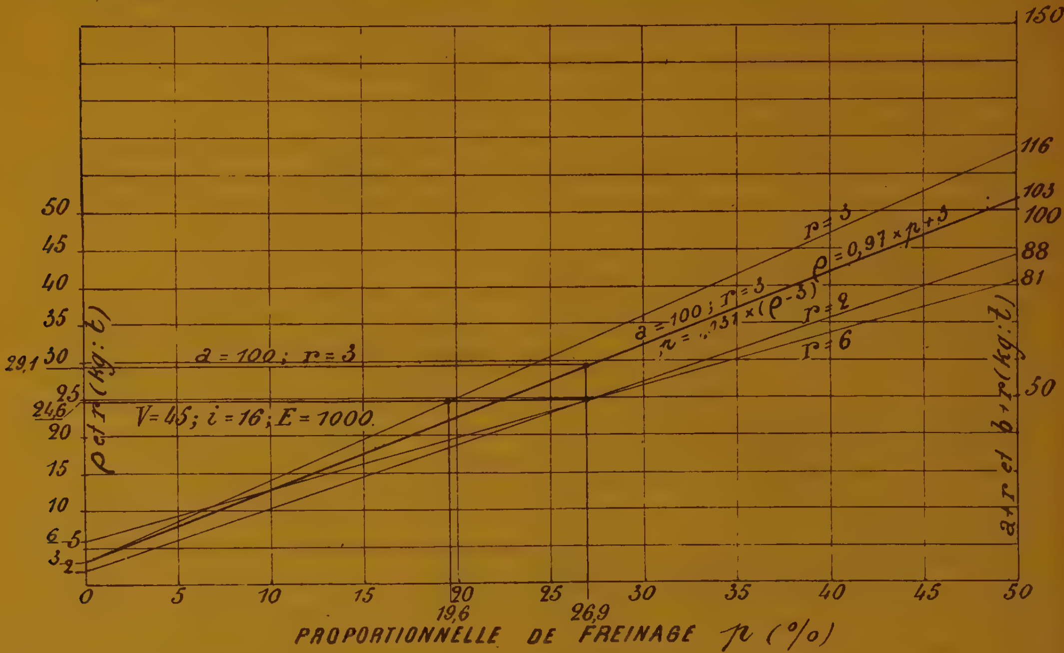

Fig. 5. — Diagram of the braked percentage p, for any given retarding force ρ, train resistance r, and the adhesion a or b.

Note. — To be reproduced on millimetre squared paper at a scale of p, 1 % = 10 mm ; ρ and r, 1 kgr. per t. = 5 mm ; a, 1 kgr. per t. = 2 mm. 5.

Explanation of French terms : Proportionnelle de freinage = Braked percentage.

On the other hand, if it is only necessary to be able to stop in a stipulated distance of 1 000 m., we can allow the speed to be increased to 56 km. (35 miles) per hour.

It will be seen that it is easy to deal with a case where the braked percentage has been reduced in consequence of a failure to one of the brakes, or of inattention on the part of one of the brakesmen.

If we wish to investigate the case of a breakaway, we will consider what will happen to the front portion, assuming the most dangerous state of affairs, namely, a broken coupling between the brake-van placed at the rear of the train in front of the assisting engine and the front portion.

The brake-vans of these trains are as a rule equal to 5 units of load, and the braked proportion of the front part of the train will be as follows :

I. — *Total weight*

Engine and tender, 36 class (tender loaded).	157.8
Train (180 — 5) × 5.5 = ...	962.5
Total weight of the front portion. . .	1 120.3

II. — *Braked weight.*

Engine and tender, 36 class (tender empty).	126.8
Train, braked units of weight : (22—5)×5.5.	93.5
Total braked weight. . .	220.3

The braked percentage has therefore fallen from 26.9 % to :

$$220.3 \div 1\,120.3 = 19.5\ (\%).$$

We can determine as before the new stopping distance for the maximum authorised speed of 45 km. (28 miles) per hour, or the new maximum speed which will allow a stop to be made in the same distance, or rather the values of a and r necessary to obtain this same result.

Thus, if $a = 100$ and $r = 3$:

for $V = 45$, we have $E = 1\,431$ m., which is the distance which is considerably greater than the stipulated 1 000 m.;

if $E = 1\,000$, the speed should be reduced to 38 km. (24 miles) per hour;

for $V = 45$ and $E = 1\,000$, ρ should $= 24.6$.

By drawing a straight line through the point on figure 5 where :

$$p = 19.6 \quad \text{and} \quad \rho = 24.6$$

if $r = 3$, then $a + r = 113$ and $a = 110$,

a value which may, in many cases, be allowed, seeing that broken couplings frequently occur at the moment when the train is passing from an up gradient to a down gradient, that is to say, at a time when the speed is low, and the value of b is higher when the initial speed is low.

In the same way one can easily examine the effect of placing the brake-van in the middle of the train, and not at the rear in front of the assisting engine. In this way one can find how much the length of 1 431 m. (1 565 yards), which was found above, will be diminished or how much the speed of 38 km. (24 miles) per hour may be increased, or how much the value of $a = 110$ may be reduced.

When it is only a question of maintaining a constant speed on a given falling gradient, it is only necessary to put :

$$\rho = i.$$

Diagram figure 5 will be very useful in this case, because the value of b will be considerably reduced when the speed is high and when the length of time during which the brake-blocks are applied to the tyres is considerable.

It often happens that continuous falling gradients are such that the brakes are applied for 15 minutes or more, although drivers, in order to make up for lost time, often considerably exceed the authorised speed limit.

It may be mentioned that the increase in the coal consumption necessary to gain time on rising gradients is so great, that it is only on long falling gradients that drivers attempt to increase the running speed, seeing that they can do so without any expenditure of fuel.

In order to investigate the results of higher speed as regards the necessary increase in the retarding force on the one hand, and the decrease of the coefficient of friction betweeen the brake-blocks and tyres on the other hand, we may make use of the diagram given in figure 5.

Let us choose a somewhat high value of r for 4, 5 or 6 kgr. per t. for example, seeing that we have now to consider the effect corresponding to a speed V, and not the effect corresponding with the average speed between V and O.

Around this value of r, we may pivot a ruler making this pass through the reduced value of b : for example 90, 80, 70 kgr. per t. in place of 100, and we read off opposite p the corresponding value of ρ.

We then draw on diagram figure 3 the sloping line $\rho - i$.

By following the rising parabolic curve of V, we can find successively values exceeding the limiting value of 45. The intersection of the ordinates with the sloping line will at once give on the scale on the left hand side the corresponding length of stop.

Diagrams figures 3 and 5 may also be used to investigate cases of breakaways.

In this case one has to assume values for E, V and ρ, seeing that it is impossible to accurately determine what the speed of the train may have been when the brakes were first applied, and one can no longer estimate the distance in which the train may be stopped without danger, and at low speeds the values of b may differ considerably from those corresponding to the maximum authorised speed.

In practice it is therefore well to investigate throughout the whole of the line under consideration what are the points at which a breakaway may constitute a source of danger, and to make a calculation for each of these, making in each case a series of assumptions in accordance with the local conditions.

The use of diagrams figures 3 and 5 also facilitates an investigation of the distances at which stop signals which are not provided with a distant signal should be visible (for example, the outer stop signals of the Belgian State Railways), taking into account the gradients, the authorised speed and the rules as regards their proportion of braked vehicles.

The only calculations which have to be made are those which give a braked percentage of the train under consideration.

The present diagrams have been prepared in the hopes that they will be useful to those who have to deal with this unsatisfactory and difficult question of hand-brakes.

It would appear that no part of this question has been finally solved. The treatise of Messrs. Gosserez and Jonet and Mr. Maison's report show that the French rules since they were put into force have been many times amended.

In Germany the same is true of « Verein's » rules.

MISCELLANEOUS INFORMATION

[621 .33]

1. — The electrification of main line railways.

(Engineering.)

There are many people who regard the electrification of British main line railways as something which is bound to occur in time, and which, indeed, would be well under way at present were it not for the conservatism of English railway engineers. Very few things, however, occur of themselves whether for good or evil, and electrification is not one of them. If it does come about, it will be an intentional change resolved on and carried through for reasons which appear sufficient to those upon whom the responsibility rests. It is quite wrong to prejudice the case by assuming that there is anything necessarily more « scientific » or otherwise commendable in hauling trains by electricity rather than by steam locomotives. The fact that electric traction was developed subsequently to steam traction is no proof that it will supersede it generally. The Duke of Wellington's comment on a newly invented steamgun, namely, that it would be the best kind of gun in the world if gunpowder had never been discovered, is applicable, *mutatis mutandis* to many devices. Electric traction has certain fairly well defined fields in which it is pre-eminent, such as, for example, the operation of dense suburban traffic on underground railways, but for long distance main line haulage its superiority over steam, under the conditions which obtain in this country, has yet to be demonstrated. We do not maintain that it cannot be demonstrated, but merely state that this has not yet been done to the satisfaction of the men who have to be convinced, while the present disagreement amongst electrical enthusiasts as to the system upon which electrification should be carried out must be modified before their general propositions are accepted.

Any argument that main line electrification must be desirable in Great Britain because certain foreign countries have found it advisable to electrify some of their important lines is quite beside the point, and it is even more inept to believe when foreign practice differs from our own, that it is necessarily worthy of imitation. We need not be envious of flat-bottomed rails spiked direct to the sleepers, adequate as they may be in other countries, nor do we desire to increase our level crossings in proportion to our bridges, to abolish platforms, or to exchange our 60 miles-an-hour expresses for trains which run with less speed, punctuality or safety. These matters, of course, have nothing to do with electrification, but as our railway engineers have given us equipment and service at least equal to anything in the world, and better than most countries can show, it is not fair to assume that they have allowed themselves to be outclassed because the Scotch express still goes North every night with a steam locomotive at its head. It is nevertheless of interest to note what progress main line electrification is making in other countries, for circumstances are continually changing and a conclusion which was valid yesterday might be overthrown to-morrow by the emergence of new conditions.

So far as Europe is concerned, the greatest development of electrification is taking place in Italy, Switzerland and France. The Italian State Railways have an electrification programme of 2 800 route miles of which 420 miles had been completed in 1922. The Swiss Federal Railways expect to have over 600 miles electrified by 1924, and their programme provides for the electrification of 1 075 miles, or 60 % of their total mileage by 1931. In France the greatest activity is in connection with the Midi Railway. A description of the work of electrification on this system was recently given before the Institution of Electrical Engineers in London by M. A. Bachel-

lery, the engineer-in-chief. Within the next ten years nearly 2 000 miles of route will be electrified in the South of France, and according to the report of M. Sabouret to the last International Railway Congress (1), the Paris-Lyons-Mediterranean, the Midi, and the Paris-Orleans railways will have between them 5 000 miles of electrified line before twenty years have passed. Germany has about 780 miles wholly or partially electrified, and the United States something like double this mileage. No other countries have anything comparable with those we have referred to, although there are few which have not something in the way of electrification either to show or in contemplation.

A summary of the present state of railway electrification abroad was given on 3 January by Professor S. P. Smith, in a lecture before the Institution of Electrical Engineers, and this, following so closely upon M. Bachellery's paper, shows that a considerable interest is taken in the subject. Much of the matter of Dr. Smith's lecture had previously appeared in the form of articles in the *Beama Journal*, which we note now appears under the title of *World Power*, but its presentation to a wider audience was well justified. Focussing, as it did, the railway electrification throughout the world within a small compass, Dr. Smith's presentation of the facts brought out a good many considerations which deserve recognition, when the question of British main line electrification is under discussion. The activity of Swiss and Italian engineers in extending electrical operations is largely due to circumstances which have no parallel in this country. Neither of these countries possesses any coal mines, and their dependence upon other nations for fuel was brought home to them in an unmistakable manner during the war. Norway and Sweden found themselves in an almost equally unenviable position, and in all these countries there was aroused a determination to utilise their own resources as far as possible. Fortunately, they all possessed water-power in large quantities, and thus circumstances combined to bring about the development of large schemes of railway electrification. France, too, is a country which is very short of coal, and it is significant, although natural, that her southern railways, alongside which water-power is abundant, should be the first to adopt electric traction on a large scale.

That the scarcity of coal has been the determining factor in most European electrification schemes is amply borne out by evidence. In the report of the Swiss Federal Council on the financial condition of the Swiss railways, presented to the International Railway Commission in 1922, we read : « The electrification of the Federal railways is an economic necessity... We must not for ever remain dependent on foreign countries which may withhold their coal, or at any rate dictate their prices without consideration for us. » Again, Mr. Ofverholm (1) commenced his report on railway electrification in Scandinavia by the words « Sweden, Norway and Denmark have not the necessary quantity of home-produced coal... In the first two countries railway electrification on a large scale has been contemplated in order to utilise water-power instead of depending on imported coal. In Denmark, owing to the lack of water-power, no such schemes are in existence ». It is quite clear from these quotations that the coal question was foremost in the minds of those who adopted the policy of electrification in the countries mentioned. It is interesting to mention that in 1920, 30.5 % of the coal burned in Switzerland came from England, 55.9 % from America, and only 6.6 % from Belgium, the Sarre or the Ruhr Valley. Germany is not so badly off for coal as the countries mentioned, but much of the Eastern coal is very poor and in Bavaria, where water-power is available, we have Dr. Smith's authority for saying that the decision to extend electric traction was hastened by the coal shortage subsequent to 1918.

In Great Britain, we have abundant coal but no hydro-electric power, so that the reason which influenced continental engineers most strongly in the development of electrification

(1) See *Bulletin of the International Railway Association*, number for January 1922, p. 107.

(1) See *Bulletin of the International Railway Association*, number for November 1921, p. 1934.

has no weight with us. It is, we think, quite fair to say that the electric operation of railways has always come about, not because of any idea of technical progress but rather because conditions under steam operation had become intolerable. The Underground system of London, the heavily loaded suburban systems in this and other countries are examples in which steam traction had reached its limitations. The change-over to electrical working is bound to go on in cases such as these, and we have instances very near home in which travellers would say that the change was already long overdue. It gives a higher average speed when stops are numerous, and enormously increases the effective capacity of the terminal stations, besides doing away with much smoke and dirt — so that a much heavier traffic can be handled with greater comfort. That electrification pays, financially, under conditions such as those of dense suburban traffic is unquestionable, though even if it dit not, it would have to be adopted if the passengers were to be moved in the time available.

The two great objections to main line electrification in Great Britain are the heavy capital cost involved and the far-reaching consequences of any failure of the electric system. The former is by far the more serious, as there is no reason why the reliability of the power supply should not be equal to that of the lighting systems in which we have become accustomed to place perfect confidence. Nevertheless it is true that no conceivable accident could completely paralyse any section of a steam railway, whereas enormous inconvenience would be brought about by the cessation of the power supply to an electrified railway, even for a very short time. To justify electrification in this country one of three facts must be demonstrated. Either it must be shown that steam haulage is no longer adequate for the traffic to be carried, or that the railways could be operated more cheaply by electricity, or that electric working would result in such an increase of traffic as to earn the interest upon the capital expenditure entailed by the conversion. All of these matters can be made the subject of fairly precise estimates, and at any rate they can be determined with at least as high a degree of certainty as is considered sufficient for other commercial enterprise to be undertaken.

In making such estimates it is quite wrong to assume that the steam locomotive has reached its limits either of power or of economy. Turbine-driven locomotives are now being supplied under a firm contract that they will do the same work as engines of the ordinary type with half the fuel consumption of the latter. A British firm has now entered into arrangements for the construction of locomotives of this type, and if they prove as successful as there is reason to anticipate it is very doubtful whether there would be any saving in fuel by transferring its combustion from the fire boxes of individual locomotives to the furnaces of large central stations, when the electrifical conversion and transmission losses are taken into account. The question of electrification of important lines in this country, however, is not to be settled by considerations of fuel economy alone, any more than it can be decided by the enthusiasm of electrical engineers on one hand, or the conservatism of established practice on the other. A close and continuous study of the conditions ought to be maintained, for as soon as ever there is a reasonable assurance that electric traction would be commercially practicable it should be adopted. Large schemes of electrification will certainly have to be carried out in the Overseas Dominions and in other parts of the world where water-power is available, and it would be of the utmost advantage to our manufacturers to be able to point out to possible clients, successfully working schemes on a large scale in this country. We cannot expect our railway companies to be philanthropists. It is their primary duty to operate their systems by the most economical means, but their secondary interest is certainly to assist the trade of the country, and anything they can do to develop a healthy business at home in electric locomotives and equipment will both benefit our export trade and prevent their own dependence upon foreign experience and material at some future time.

[385. (09.2]

OBITUARY

E. H. STIELTJES,

Civil Engineer;
Honorary President of the Committee of Inspection of the Dutch Railways;
Formerly a member of the Permanent Commission of the International Railway Congress Association;
First delegate
of the Netherlands Government at the seventh session of the Congress (Washington, 1905).

We have learned with deep regret of the sudden death, on the 23 December last, of Mr. E. H. Stieltjes, who was for twelve years (1911 to 1922) one of the most devoted members of the Permanent Commission of the International Railway Congress Association.

Born at Gramsbergen on the 28 September 1853, Mr. Stieltjes left the Polytechnic College at Delft in 1874 with the degree of civil engineer. As early as 1874 he was entrusted by the Commercial Union of Rotterdam with the design and carrying out of numerous works. After this he was, in 1876, assistant engineer to the « Nederlandsch-Westphaalsche Spoorwegmaatschappij » at Winterswijk; in 1879 assistant engineer on the construction of lines on State Railways at Arnhem, Oosterbeek, Rhenen and the Hague, and in 1882, engineer to the Rhine Canal Committee at Amsterdam and the Hague. From the 1 January 1886 to the 1 April 1892 he was editor of *De Ingenieur*. On the 1 April 1892 the Netherlands Government appointed him a member of the Committee of Inspection of Railways, of which he became President on the 1 January 1913.

He was a Chevalier of the Orders of the « Lion Néerlandais » and of the « Légion d'honneur ».

Mr. Stieltjes was an engineer of high standing, a man of sterling character, and had a highly sympathic personality. He followed closely and with deep interest the work of the Permanent Commission, and it can truly be said that its members appreciated highly the friendship he ever extended to them.

We offer to the family of our late and respected colleague our most sincere sympathy at their loss.

The Executive Committee.

NEW BOOKS AND PUBLICATIONS

[385. (02 & 385. (04]

VANDERRYDT (H.), professor at the University of Brussels, & MINSART (E.), engineer of the Belgian State Railways. — **Cours d'exploitation des chemins de fer (Series of lectures on railway operation)**, 2 volumes in 8vo (10 1/2 × 7 1/2 inches) of 422 and 318 pages with numerous illustrations. — 1923, Librairie polytechnique Ch. Béranger, 15, rue des Saints-Pères, Paris, and 8, rue des Dominicains, Liége. — Price : 100 francs to subscribers.

These books consist of the lectures given at the Polytechnical School of the University of Brussels by Mr. H. Vanderrydt.

They are divided into three sections; the first two, which deal with the *Permanent Way and Rolling Stock,* make up the first volume, whilst the third section, which deals with *Technical Operation,* is the subject of the second volume.

The syllabus of the lectures has been drawn up so as to cover in the best possible way the subjects indicated by the title. They deal, in a concise form, with the principles and methods employed and the essential parts and characteristics of the rolling stock.

The descriptive matter is illustrated by diagrams, and in cases where it is necessary, by illustrations of the actual form of the article under discussion, and where possible, the main dimensions of the chief parts are given. These illustrations, which include no unnecessary details, are more easily understood and remembered, because they are simpler and more striking, and better in keeping with the spirit of the work, than are diagrams which give a complete reproduction of the working drawings as prepared in the drawing office. The examples chose are taken, not only from the Belgian railways, but also from other railway administrations in Europe and America. This is particularly the case where it is desired to call attention to interesting types of rolling stock, to compare different arrangements or to discuss innovations which are being experimented with. In many cases references are given at the bottom of the page to allow the reader, if he wishes, to ascertain in what publication he may find further or more detailed information of the point being dealt with.

The first part commences with a chapter entitled : « Laying out a Line », which deals with the economic and technical considerations which should be considered by the engineer who is studying the lay-out of a line. The three following chapters deal with the establishment of the formation, the materials for the permanent way, the lay-out of the track on the straight and on curves, the special apparatus used and the trucks employed for transporting material.

The question of rolling stock is divided into four chapters, *viz.,* the train, the coach body, the lighting of trains, and heating and ventilation. Although the authors have not dealt here with the strength of materials used in the construction of locomotives, as they believe they can be better dealt with in another place, they have found it desirable to deal with certain special points, such as calculations of the design of frames, springs and axles.

Naturally the steam locomotive occupies a prominent place in the book. The question of the calculation of the principal dimensions gives rise to an analysis of the various factors which enter into train resistance, and formulæ are

given for evaluating these. The output and efficiency of a boiler is dealt with in the light of specially conducted tests, which give more satisfactory and correct results than if one deals with more or less weak hypotheses.

The description of the boiler itself is dealt with fully, as is necessary with this special type of steam raiser. The results are given of recent interesting experiments with liquid fuel, pulverised coal, different types of superheaters, and feed water heaters using exhaust steam. Mention is made of recent researches on the question of the draught.

With regard to the engine, the effect of the number of cylinders, and of compounding or superheating, on the variation in the turning moment, and also on the efficiency, is dealt with.

The locomotive as a vehicle and its stability are complicated questions, and they are discussed in view of the best researches into these points. The question of running round a curve, often studied as a question of pure geometry, is dealt with taking into account the effect that friction has in retarding the transverse displacement of the axles.

The last chapter of the second part (rolling stock) is devoted to brakes, beginning with the method of retarding the train by reversing the engine. Very wisely the subject matter is confined to the principles of their working, eliminating reference to details of construction of the various parts, which can always be found in makers' catalogues.

In the second volume — « Technical Operation » — will be found matters relating to the running of trains, their make-up, braking, safety and regularity of running, and their organisation and operation. Two specially important subjects are dealt with : stations and signalling. These perhaps properly come under the designation of works, but owing to their nature and their importance from a traffic standpoint, have a direct bearing on operation.

The first chapter of the second volume (the nineteenth of the series) deals with various points affecting the problems of transport. These include the methods employed for calculating the loads of the trains and time occupied in covering a journey, allows of the checking of timetables settled by experience, and determining in advance the loads of proposed new types of locomotives and the work that they ought to perform, and especially, if one has figures of similar engines, of ascertaining the power and coal consumption at various speeds. There then follows in the section dealing with the « choice of power » a concise analysis of the different types of locomotives actually employed, their principal dimensions and the work they can carry out being given.

Stations are classed as ordinary and special, *i. e.*, large passenger stations, sorting stations, large goods stations and shunting and marshalling sidings. The examples chosen show the application of regulations, having for their object economical operation and the easy flow of traffic. This chapter also deals with the locomotive sheds, the organisation of which is becoming more and more perfect.

The question of signalling is dealt with in three chapters. The first of these deals with the signals properly so called. It includes cab signals, which have been the subject of numerous inventions and which ought to be developed. The second explains the principles and methods of signalling; amongst the examples given are a certain number relating to the three-position signals which have been adopted on the Belgian State Railways. The third chapter is devoted to the lay-out of signal frames and is noteworthy in that it contains a complete theory of interlocking. In it are also described the power operated signal boxes for which purpose electricity is coming more and more into use.

Working on the block system is dealt with in another chapter, where the methods employed of protecting running trains are described. Mention is also made of the automatic block operated by track circuits, both on steam and on electrically operated lines, and of the use of lighted signals during the day, which system has been applied at several points lately.

The last two chapters are devoted to the organisation of train services, to the different types of trains, to the question of timetables, to control and dispatching systems, to the use and distribution of stock, and the transport of passengers, luggage and goods at high and low speeds.

It would take far too long to give a complete review of this work. We have, we believe, said enough to show that we have in it a series of lectures dealing with the latest studies of the subject and the application of them practically.

[621 .33 (02 & 385. (04]

MANSON (Arthur J.). — **Railroad electrification and the electric locomotive.** — One volume (8 3/4 × 5 1/2 inches), of VIII + 332 pages, with 149 diagrams and photographs and numerous tables. — 1923, Published by Simmons-Boardman Publishing Company, 30, Church Street, New York, U. S. A., and 34, Victoria Street, Westminster, London, S. W. 1. — Price : $4 or 18 sh. 6 d.

The Author of this book is the Manager of the Transportation Division of the Westinghouse Electric & Manufacturing Company of New York, and much of the material appeared originally in certain American Engineering Magazines. It may be said at once that it is not a book intended for the expert electrical railroad engineer, as may be judged from the fact that the whole subject is covered in 30 chapters extending over less than 300 pages. It however should appeal to a considerable number of engineers on both sides of the Atlantic, as it gives in simple language the points of the various details of the application of electrical working of railroad locomotives.

The earlier chapters are devoted to a somewhat elementary description of electrical phenomena and to the working of various types of motors, etc.

The Author then passes to the various parts of the locomotive and the methods of supplying and controlling the current.

One of the largest chapters in the book is devoted to the mechanical methods of transmitting the drive from the motor to the wheels, and it is to be regretted that the developments of this most interesting and important subject, in Switzerland and elsewhere in Europe, are only very briefly touched upon, and no mention is made of some of the latest types.

This is followed by a detailed consideration of the speed-time curve. Two chapters are devoted to dealing with the various points which have to be considered in a definite electrification problem and their application to particular assumed conditions.

The manuscript ends with a short description of all the railroad electrification schemes which have been carried out in the United States of America, and this is supplemented by a number of tables of particular schemes.

The usefulness of the book would have been increased if more up-to-date information with regard to European practice generally, in addition to the special point mentioned, had been added.

H. F.